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SEASONAL SUCCESSION, SOIL RELATIONS, NUMBERS, AND REGIONAL DISTRIBUTION OF NORTH-EASTERN TEXAS ACRIDIANS

By

F. B. ISELY

Trinity University, Waxahachie, Texas

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SEASONAL SUCCESSION, SOIL RELATIONS, NUMBERS, AND REGIONAL DISTRIBUTION OF NORTH-EASTERN TEXAS ACRIDIANS

INTRODUCTION

For the past six years, 1931-1936,[1] the writer has been carrying on field and experimental studies bearing on the *ecology of orthopterous insects* both in Texas and Colorado.[2] In these researches an attempt is being made to evaluate the environmental factors that enter into the lives of these plastic insects.

The accumulated data from my field and experimental notes pertaining to seasonal succession, general soil relations, relative numbers of the more populous northeastern Texas acridians (shorthorned grasshoppers), and regional distribution within northeastern Texas are summarized in this paper. A second paper dealing with ACRIDIAN PLANT AND SOIL RELATIONS based on further critical field and experimental studies is in preparation.

LITERATURE

A number of workers have made valuable contributions to acridian ecology. The papers that have been available and helpful are: Vestal ('13, '24), Fox ('14), Morse ('20), Uvarov ('28, '31, '32), Gause ('29), Parker ('30), Faure ('32), Criddle ('33), Diver and Diver ('34), Ross in Hebard ('34), Lean ('36). Concerning Texas acridians specifically[3] very little has been published, although references to Texas acridians and other orthopteran species[4] figure prominently in the taxonomic literature. Among the papers that have been helpful in understanding the taxonomy and relationships of Texas acridians are the following: Caudell ('03), Hart ('06), Morse ('07), Rehn and Hebard ('09), Rehn ('19), Blatchley ('20), Little ('26), Hebard ('28, '31, '33, '34, '36), Isely ('34, '35).

TAXONOMY AND BEHAVIOR

The acridian species are for the most part quite distinctive either "in hand" or "in the bush." Morphological characters of form and color are more or less outstanding. Activities in flying, whirring, stridulating (Isely, '36), jumping, ducking, sliding, slinking, sneaking, dodging, freezing, and color flashing are as characteristic of grasshoppers as similar activities are

[1] During 1935 and 1936 the writer has been assisted in these investigations by a grant-in-aid from the National Research Council.

[2] Colorado, summers 1931 (Boulder) and 1932 (Rocky Mountain Biological Laboratory, Crested Butte).

[3] The series of critical studies by Hebard on the Orthoptera of Colorado, Kansas, Illinois, and other states has been indispensable. The publication of Hebard's "Orthoptera of Texas" now in the press will be of great assistance in further researches dealing with grasshoppers and other orthopterous insects in Texas.

[4] Chiefly because of the thorough scientific collecting in northeastern Texas by such pioneer naturalists as Jacob Boll (1869-81) and Gustaf W. Belfrage (1867-82). See Isely, '35.

characteristic of birds and other vertebrates. To the experienced field worker these behavior activities are helpful identification aids in census and population studies and in estimating comparative numbers. However, a number of species are not easy to diagnose even in hand, but here also seasonal and habitat preferences give the experienced field student an advantage not always at the command of the taxonomic and museum experts.

ACKNOWLEDGMENTS

I am glad to express my appreciation for help which I have received from many sources during the progress of these studies. Each of the following students, friends, or members of my immediate family have given expert assistance in field studies during the past five years for one or more seasons: Martha B. Rettig, J. C. Chapman, Frank Lander, J. C. Byars, E. L. Dunaway, Jean Wilson, Mary Broadwell, Gordon Tucker, Joe Bowman Douglas, Joe Cantrell, E. J. Harpole, Ruth Dillon, Harold N. Isely, Ralph D. Isely, Frederick B. Isely, Jr.

Suggestions pertaining to literature, methods, or materials for study have been generously given by Drs. W. C. Allee, A. G. Vestal, S. W. Geiser, W. M. Winton, E. P. Cheatum, B. B. Harris, and Mr. and Mrs. Ottys Sanders.

I am especially indebted to Dr. Gordon Alexander for helpful suggestions regarding the manuscript, to Mr. Morgan Hebard for help in acridian taxonomy, to Mary Ellen Douglas and Robert White for technical assistance, and to my wife, Mary N. Isely, who has assisted me at every turn in field and experimental studies.

THE AREA

Physiographically, northeastern Texas is a dissected plain. The soils (Carter, '31) fall into three chief groups: (1) the calcareous soils designated on soil maps as the "blackland prairies" and the "grand prairies"; (2) the arenaceous soils of the sandy "east Texas timbers," the "east cross timbers" and the "west cross timbers"; (3) alluvial soils, usually various combinations that have been derived from 1 or 2, or from 1 and 2, i. e., blackland prairies or grand prairies or sandy east Texas cross timbers. The primitive vegetation cover of the first two groups has already been indicated as prairies and timbers, in the former there were interspersed timbered areas, in the latter the soils of the open woods were covered with grasses and broad-leaved plants. The alluvial soils in their primitive condition were heavily wooded.

For purposes of this paper only, broad, general soil differences are taken into account. Later it is hoped that habitats and micro-habitats as they involve soils, evaporation, humidity, temperature, related vegetation, and other biotic factors of orthopteran communities may be reported.

Acridian soil relations are clearly specific, and with the present detailed soil maps of many counties in Texas and other states approximate checking

of soil relations is practical. In fact, my field records show that every specific type of soil[5] that has been worked with some detail has its own distinctive seasonal and annual acridian fauna as well as flowering plant flora. The *primary* controlling environmental factor in local distribution is doubtless the soil. Plants and vegetative soil cover, as they are related to food, protection, temperature, and humidity in the micro-habitats, are *indirectly* significant for acridians. That is to say, plant distribution and the extent and vigor of plant growth are definitely soil-related, and soil make-up is a determining factor in the choice of egg laying sites by many species. In Ellis County the soil maps[6] show thirteen distinctive soil types, and in Dallas County eighteen soil types are shown; both of these counties are in the blackland prairie belt, and soil conditions are fairly uniform. Here soil conditions are more uniform than in many areas of equal extent; for example, Tarrant County, Texas, or a mountain-plains area as Boulder County, Colorado.

The map (Fig. 1) outlines the extent of northeastern Texas, as considered in this paper, extending east to west from Marshall to Palo Pinto a dis-

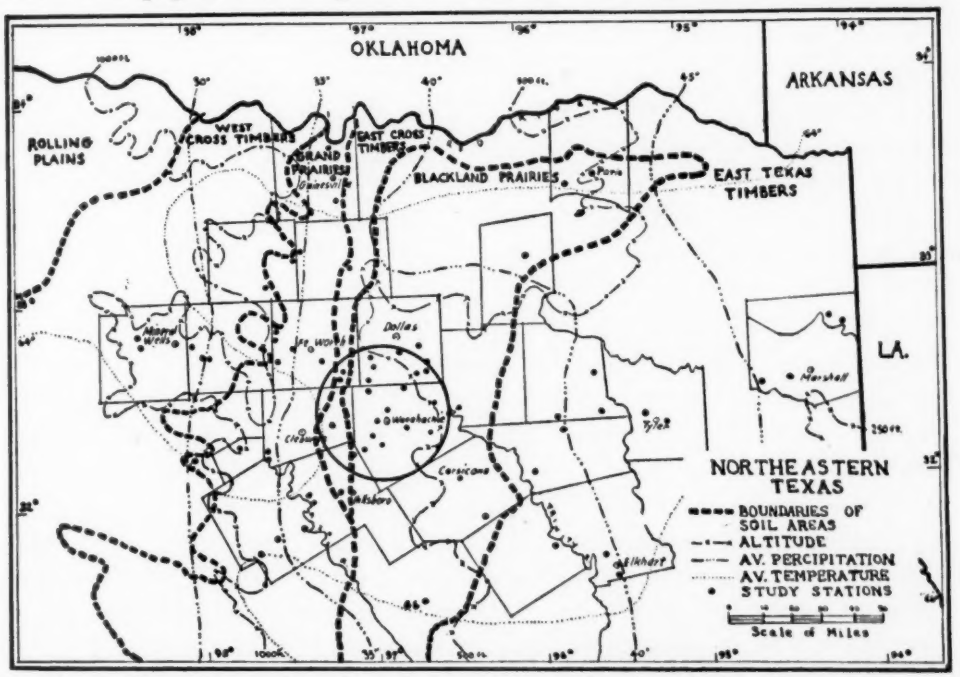

FIG. 1. Map of a portion of northeastern Texas showing chief study stations, central area in circle where intensive seasonal and soil relations were investigated, and larger area where regional distribution has been studied.

[5] Some of the important soil types where study stations are located in Ellis and Dallas Counties are the following: Houston black clay, Houston clay, Houston clay shallow phase, chalk, Ellis clay, Trinity clay, Durant fine sandy loam, Durant very fine sandy loam, Cahaba sand, et al; in Tarrant and Johnson Counties Kirvin fine sandy loam, Kirvin fine sandy loam eroded phase, and its various other phases as well as Tabor fine sandy loam.

[6] Thirteen distinct types of soil are found in Ellis County (Bennett, '11) ranging in texture from fine sand to stiff clay. All of these soils with the exception of the Trinity clay and the Cahaba fine sand, have been derived from the weathering of materials of the Cretaceous Age. During this period the entire region was covered by a sea which received vast deposits of sediments from the streams that emptied into it. At the close of the period the land was elevated above the sea and subsequent weathering of the materials has produced the various soils.

tance of 250 miles, and north to south from Gainesville to Elkhart a distance of 150 miles. The mean annual temperature of this Texas region varies only one degree; i. e., it ranges from 65-66° F. The altitude varies from 400 feet on the east to over 1,000 feet on the west; the annual rain-fall ranges from 30 inches on the west to 45 inches on the east; the area as a whole is placed in the humid belt, although approaching the semi-humid characteristics in the western portion (Carter, '31).

FIELD AND EXPERIMENTAL WORK

The field stations within the blackland prairie belt and in the east cross timbers, as found in Ellis, Dallas, Johnson, and Tarrant Counties (shown in circle, Map, Fig. 1) have been the focal centers of my seasonal succession and soil relations studies for the past six years. All of these stations are within forty miles of Waxahachie, Texas, and thus have been accessible for frequent checking. While the central area has thus been intensively studied, other more distant sections of northeastern Texas, shown on the map by study stations, have also been investigated. Only ten days have been spent in the east Texas timber country and nine days at stations in the grand prairies. The west cross timbers were checked in three study trips: three days in August, 1934, two days in May, 1935, and two days in late June, 1936. The east Texas timber (Smith, Anderson, and Harrison Counties) acridian faunas as well as the west Texas timber and grand prairie (Parker, Palo Pinto, and Bosque Counties) acridians when compared with the blackland prairie (Ellis and Dallas Counties) acridians are quite distinctive (Map, Fig. 6) and may well be grouped as eastern, middle, and western acridian faunas within northeastern Texas.

In addition to the year-round field researches outlined above, for the past three years (1934-36) constant cage and garden enclosure observations and experiments have been under way. These experimental studies have supplemented field observations and have been of help in evaluating field deductions.

During the six years that this work has been in progress, 212 recorded field study trips within northeastern Texas have been made, and over 14,000[7] specimens representing 87 acridian species have been studied in attempting to arrive at comparative density values and the distribution of the various species during the periods of their seasonal activity.

A great deal of detailed faunistic survey work (Isely, '34, '35) has been necessary as a beginning toward the understanding of the taxonomy and distribution of the eighty-seven species concerned. The immediate area is rather intensively developed agriculturally, and even an approach to primitive conditions has often been very difficult to secure. In the selection of stations, soil differences and consequent correlated vegetation differences, as

[7] Thoroughness in checking on field study trips has been made possible through the generous cooperation and help of assistant collectors. On at least 90 per cent of my field trips I have had the efficient help of one to three assistant collectors.

well as topographic and other less evident habitat differences, have been taken into account in an effort to discover as many types of acridian habitats and micro-habitats as possible.

FIELD DATA APPLIED TO SPECIES

Of the eighty-seven northeastern Texas acridian species studied (Isely, '35), fifty-one fairly common species were within range from my home (Waxahachie, Texas) for year-round checking. Data concerning these fifty-one blackland prairie and east cross timber acridians are tabulated herein. The species listed in Tables 1-3 are grouped on the basis of general soil relations. Comparative population density is in part indicated by recording the total number of individuals checked in the field records during the six years these investigations have been in progress. Seasonal variation within the species is indicated in month to month comparisons by the well known frequency terms much used by field students of populations in all sorts of plant and animal studies. These frequency criteria as used in this paper are fully defined in a later section.

TABLE 1. SHALLOW SOIL ACRIDIANS

All frequency records are for adults. Juveniles are indicated if found when adults were not present. The total numbers of adults checked in field records for each species are given in the last column.

Jv. Juveniles R. Rare | If. Infrequent Oc. Occasional | Fr. Frequent Cm. Common | Ab. Abundant Sw. Swarms

SPECIES	MONTHS											NUMBERS
	January-February	March	April	May	June	July	August	September	October	November	December	
1. Mesochloa abortiva Bruner	Fr.	Fr.	Fr.	Oc.	.....	.....	.....	Jv.	Cm.	Cm.	Cm.	175
2. Eritettix simplex (Scudder)	Jv.	Oc.	Fr.	Oc.	.....	.....	.....	.....	.....	Jv.	Jv.	77
3. Arphia conspersa Scudder	Jv.	Fr.	Fr.	If.	.....	.....	.....	.....	.....	Jv.	Jv.	59
4. Melanoplus confusus Scudder	Jv.	Jv.	Cm.	Ab.	Oc.	If.	.....	.....	.....	.....	.....	258
5. Xanthippus corallipes pantherinus (Scudder)	Jv.	Jv.	If.	Cm.	Cm.	Fr.	If.	.....	.....	Jv.	Jv.	168
6. Acrolophitus variegatus (Thomas)	.....	Jv.	Jv.	Cm.	Cm.	If.	R.	.....	.....	.....	.....	132
7. Melanoplus texanus (Scudder)	.....	Jv.	Jv.	Ab.	Ab.	If.	R.	.....	.....	.....	.....	375
8. Paraidemona punctata (Stäl)	.....	.....	Jv.	Jv.	Sw.	Fr.	If.	R.	.....	.....	.....	328
9. Dactylotum pictum (Thomas)	.....	.....	Jv.	Jv.	Ab.	Ab.	If.	If.	R.	.....	.....	225
10. Melanoplus flabellatus Scudder	.....	.....	Jv.	Jv.	Cm.	Cm.	Fr.	Fr.	If.	.....	.....	165
11. Hesperotettix v. viridis (Thomas)	.....	.....	Jv.	Fr.	Cm.	Ab.	Cm.	Fr.	Oc.	If.	.....	283
12. Hesperotettix speciosus (Scudder)	.....	.....	Jv.	Fr.	Cm.	Ab.	Cm.	Cm.	Oc.	If.	.....	239
13. Ageneotettix deorum (Scudder)	.....	.....	.....	Jv.	Fr.	Cm.	Cm.	Fr.	Oc.	If.	.....	284
14. Hadrotettix trifasciatus (Say)	.....	.....	.....	Jv.	Fr.	Ab.	Cm.	Fr.	Oc.	If.	.....	312
15. Trimerotropis pistrinaria Saussure	.....	.....	.....	Jv.	If.	Cm.	Cm.	Cm.	Fr.	Oc.	If.	259
16. Melanoplus discolor (Scudder)	.....	.....	.....	Jv.	Jv.	Cm.	Cm.	Fr.	Fr.	Oc.	If.	156
17. Melanoplus plebejus (Stäl)	.....	.....	.....	.....	.....	Jv.	Fr.	Fr.	Oc.	Oc.	If.	123
18. Trachyrachis kiowa fuscifrons (Stäl)	R.	If.	If.	Oc.	Cm.	Ab.	Ab.	Ab.	Cm.	Cm.	If.	259
19. Melanoplus m. mexicanus (Saussure)	.....	Jv.	Oc.	Oc.	Oc.	Oc.	Oc.	Oc.	Oc.	If.	If.	203
TOTAL	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4,080

TABLE 2. LIGHT SANDY SOIL ACRIDIANS

All frequency records are for adults. Juveniles are indicated if found when adults were not present. The total numbers of adults checked in field records for each species are given in the last column.

Jv. Juveniles If. Infrequent Fr. Frequent Ab. Abundant
R. Rare Oc. Occasional Cm. Common Sw. Swarms

SPECIES	MONTHS											NUMBERS
	January-February	March	April	May	June	July	August	September	October	November	December	
1. Amblytropida occidentalis (Saussure)	Fr.	Fr.	Fr.	If.	.....	.....	.....	Jv.	Fr.	Fr.	Fr.	61
2. Schistocerca d. damnifica (Saussure)	Fr.	Fr.	Fr.	If.	.....	.....	.....	.....	Jv.	Jv.	Fr.	64
3. Psoloessa t. texana (Scudder)	Jv.	Fr.	Fr.	If.	If.	.....	.....	.....	.....	Jv.	Jv.	58
4. Pardalophora saussurei (Scudder)	Jv.	Jv.	If.	Ab.	Ab.	Cm.	If.	If.	.....	.....	Jv.	212
5. P. phoenicoptera (Burmeister)	Jv.	Jv.	If.	Oc.	Oc.	If.	If.	.....	.....	.....	Jv.	29
6. Spharagemon collare cristatum (Scudder)	.....	Jv.	Jv.	Ab.	Ab.	Ab.	Cm.	Cm.	Cm.	Fr.	If.	278
7. Melanoplus impiger Scudder	.....	.....	Jv.	Sw.	Sw.	Ab.	Cm.	Cm.	Fr.	Oc.	If.	395
8. Melanoplus glaucipes (Scudder)	.....	.....	.....	Jv.	Oc.	Oc.	Oc.	If.	.....	.....	.....	31
9. Spharagemon bolli Scudder	.....	.....	.....	Jv.	If.	Oc.	Oc.	Oc.	.....	.....	.....	39
10. Schistocerca lineata Scudder	.....	.....	.....	Jv.	Jv.	Fr.	Oc.	Oc.	If.	.....	.....	46
11. Arphia xanthoptera (Burmeister)	.....	.....	.....	.....	Jv.	If.	Oc.	Oc.	Oc.	If.	If.	54
TOTAL	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,267

TABLE 3. DEEP SOIL ACRIDIANS

All frequency records are for adults. Juveniles are indicated if found when adults were not present. The total numbers of adults checked in field records for each species are given in the last column.

Jv. Juveniles If. Infrequent Fr. Frequent Ab. Abundant
R. Rare Oc. Occasional Cm. Common Sw. Swarms

SPECIES	MONTHS											NUMBERS
	January-February	March	April	May	June	July	August	September	October	November	December	
1. Chortophaga viridifasciata (DeGeer)	Jv.	Fr.	Cm.	Cm.	Fr.	Fr.	Fr.	Fr.	Oc.	Oc.	If.	233
2. Schistocerca a. americana (Drury)	Oc.	Oc.	If.	If.	If.	If.	Oc.	Ab.	Ab.	Ab.	Cm.	194
3. Encoptolophus sordidus costalis (Scudder)	Oc.	Oc.	Oc.	Oc.	Oc.	Fr.	Fr.	Cm.	Cm.	Cm.	Cm.	195
4. Arphia simplex Scudder	Jv.	Jv.	If.	Ab.	Ab.	Ab.	Cm.	Cm.	Oc.	If.	If.	351
5. Trimerotropis citrina Scudder	.....	.....	Jv.	Fr.	Fr.	Fr.	Fr.	Fr.	Fr.	If.	If.	109
6. Dissosteira carolina (Linnaeus)	.....	.....	Jv.	If.	Oc.	Oc.	Oc.	Oc.	If.	If.	.....	62
7. Boopedon maculatum Caudell	.....	.....	Jv.	Jv.	Ab.	Fr.	Oc.	If.	.....	.....	.....	183
8. Melanoplus bispinosus Scudder	.....	.....	.....	Jv.	Oc.	Fr.	Oc.	Oc.	Oc.	If.	.....	142
9. Mermiria m. maculipennis Bruner	.....	.....	.....	Jv.	If.	Ab.	Ab.	Cm.	Oc.	R.	.....	352
10. Melanoplus differentialis (Thomas)	.....	.....	.....	Jv.	Fr.	Sw.	Ab.	Ab.	Ab.	Oc.	.....	338
11. Melanoplus p. ponderosus Scudder	.....	.....	.....	Jv.	Fr.	Cm.	Cm.	Fr.	Oc.	If.	If.	129
12. Mermiria neomexicana (Thomas)	.....	.....	.....	.....	Jv.	If.	Cm.	Cm.	Oc.	If.	.....	94
13. Orphulella speciosa (Scudder)	.....	.....	.....	Jv.	Oc.	Oc.	Cm.	Cm.	Cm.	Fr.	Oc.	141
14. Syrbula admirabilis Uhler	.....	.....	.....	.....	Jv.	Oc.	Ab.	Ab.	Cm.	Fr.	.....	388
15. Hippiscus rugosus (Scudder)	.....	.....	.....	.....	Jv.	Cm.	Cm.	Cm.	Oc.	If.	If.	184
16. Encoptolophus subgracilis Caudell	.....	.....	.....	.....	Jv.	Fr.	Fr.	Fr.	Oc.	Oc.	If.	82
17. Dichromorpha viridis (Scudder)	.....	.....	.....	.....	.....	Jv.	Oc.	Fr.	Oc.	If.	.....	67
18. Schistocerca obscura (Fabricius)	.....	.....	.....	.....	.....	Jv.	Oc.	Oc.	Oc.	If.	If.	76
19. Melanoplus k. keeleri (Thomas)	.....	.....	.....	.....	.....	Jv.	Fr.	Fr.	Fr.	Oc.	If.	104
20. Campylacantha o. olivacea Scudder	.....	.....	.....	.....	.....	Jv.	If.	Fr.	Fr.	Oc.	If.	143
21. Melanoplus scudderi latus Morse	.....	.....	.....	.....	.....	Jv.	Fr.	Fr.	Fr.	Oc.	Oc.	125
TOTAL	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4,119

SIGNIFICANCE OF TABULAR DATA

Tables 1-3 present the condensed accumulated data that will be discussed under the sub-titles of soil relations, seasonal succession, and populations.

SOIL RELATIONS

The species making up the three tables have been grouped according to their soil preferences. A number of critical field students of American acridians (Morse, '20; Vestal, '24; Criddle, '33; Ross, '34) have commented upon the close relationship of acridians to varying soil types. It was this evident relationship, impressed upon the writer in a preliminary study (Isely, '05), that motivated the present investigations.

FIG. 2. Whiterock slope, Day's Ranch, Cedar Hill, Dallas County, Texas. July 29, 1936.

SHALLOW SOIL ACRIDIANS, TABLE 1.—Several of the grasshopper species listed in Table 1 as shallow soil acridians frequent the bare soils or eroded subsoils. Others find shelter among the weeds and grass clumps characteristic of shallow upland soils. The topography of these upland soils is rough or rolling. The soils at our study stations in Ellis and Dallas Counties are chiefly Houston clay, Houston stony clay shallow phase, or chalk and are essentially a calcareous soil series. To this calcareous series should be added eroded stretches of Kirvin fine sandy loam subsoil found at the writer's cross timber stations as these eroded soils are sometimes frequented by *Hadrotettix trifasciatus* (Say) and *Trimerotropis pistrinaria* Sauss.

Figure 2 pictures an eroding slope of chalk and Houston stony clay shallow phase, locally known as "whiterock" land. This is a climax July-September habitat of *Trimerotropis pistrinaria* Sauss. A common associate during these months is *Hadrotettix trifasciatus* (Say). This same slope and the adjacent higher land is a winter and spring habitat of juveniles of *Xanthippus corallipes pantherinus* (Sc.) and adults of *Mesochloa abortiva*

Bruner. However, *X. c. pantherinus* (Sc.) in its adult stage moves for most of its feeding activity to adjacent deep soil heavy grass-covered areas but returns to shallow soil for oviposition. All grasshoppers listed in Table 1 have been collected as frequent to abundant species during the last three years in the immediate vicinity of the area pictured in Figure 2.

LIGHT SANDY SOIL ACRIDIANS, TABLE 2.—The light sandy soil acridians listed in Table 2 were restricted for the most part to our sandy soil study stations in Johnson and Tarrant Counties. The soils are chiefly Kirvin fine sandy loam, Kirvin fine sand, and Tabor fine sandy loam; while in Dallas County where several species were studied the writer's sandy soil study stations were located on Cahaba and similar sandy soils.

FIG. 3. Weedy pasture, Park Woods, Alvarado, Texas. August 4, 1935.

Figure 3 represents a typical weedy pasture of the sandy east Texas cross timbers. The area here pictured is a May-June climax habitat of *Pardalophora saussurei* (Sc.), and a month later it may become a June-July optimum habitat of *Melanoplus impiger* Sc. and *Spharagemon collare cristatum* (Sc.). All other species listed in Table 2 have been found during the last five years as occasional to common acridians in the adjacent open woods shown in the background.

DEEP SOIL ACRIDIANS, TABLE 3.—The species listed in Table 3 are characteristic of a number of different types of deep soils. Here are included acridians found at stations where such residual soils as Houston black clay or alluvial soils as Trinity clay occur. In addition to these are included study stations on Bell clay and Ellis clay. As would be expected Table 3 presents a less homogeneous acridian assemblage than do the species listed in Tables 1 and 2.

Figure 4 pictures a level tract of old stream terraced land, Bell clay. The July-September vegetation consists largely of bermuda grass and broomweed. The adult acridians of this area during the late summer and fall are

Syrbula admirabilis Uhler, *Hippiscus rugosus* (Sc.), *Encoptolophus sordidus costalis* (Sc.), *Melanoplus k. keeleri* (Thos.), and *Campylacantha o. olivacea* Sc.

Under Table 3 are grouped together several of the dominant grasshoppers of northeastern Texas: *Arphia simplex* Sc., *Melanoplus differentialis* (Thos.), *Mermiria m. maculipennis* Bruner, and *Syrbula admirabilis* Uhler. The topography of Texas deep soil stations is usually flat but sometimes rolling. The vegetation cover, except in over-grazed pastures, is often a heavy turf of thick grasses characteristic of the primitive blackland prairies. However, the alluvial soils are frequently covered with coarse weeds and grasses, especially sunflower (Helianthus), giant ragweed (Ambrosia), and Johnson grass (Sorghum), or in the well managed pastures these soils are covered with bermuda grass (Cynodon).

FIG. 4. Old stream terrace, bell clay, Jordan's Pasture, Sardis, Texas. June 22, 1935.

BLACKLAND PRAIRIES.—Here are brought together blackland prairie acridians represented by *Mermiria m. maculipennis* Bruner and *Mermiria neomexicana* (Thos.). Frequently associated with the Mermirias but not strictly belonging to the same biotic community will be *Syrbula admirabilis* Uhler, *Melanoplus bispinosus* Sc., and other acridian species less numerously represented.

LOW OPEN WOODS.—The timber margin, low open woods, and creek margin habitats are represented in Table 3 by *Dichromorpha viridis* (Sc.), *Chortophaga viridifasciata* (DeG), *Melanoplus scudderi latus* Morse, *Campylacantha o. olivacea* Sc., and *Melanoplus k. keeleri* (Thos.). The last four species are very widely distributed among varying habitats as well as having an extensive geographical range.

ALLUVIAL AREAS.—In the alluvial and drift soil assemblage in northeastern Texas we frequently find *Trimerotropis citrina* Sc. and *Dissosteira carolina* (L.) associated, while among the rank weeds and coarse grasses grow-

ing on these alluvial soils *Melanoplus differentialis* (Thos.), *Schistocerca a. americana* (Drury), and *Schistocerca obscura* (Fab.) find their optimum habitats. The other species in Table 3 need individual treatment to be satisfactorily located in their optimum surroundings.

SEASONAL SUCCESSION

The constant kaleidoscopic shifting of the panorama of nature even in a limited locality is always a feature of dramatic interest to the student of year around organismal activity. Birds, flowers, insects (Bromley, '34), and many other forms of plant and animal life come and go with more or less clock-like regularity, and at the same time they fit into rather precise date niches in the annual review of the intricate seasonal web. The succession of events is striking and well marked among the acridians, and apparently closely inter-related with the floral calendar that marks seasonal succession among the seed plants and other animals of northeastern Texas.

Considering the three tables as a whole, the following grouping into five overlapping seasonal periods may serve to emphasize the seasonal niches of adult activity occupied by many of our acridians. Acridians are definitely associated with high temperatures, hence April and May are perhaps the best months to usher in a seasonal review as it is found under the climatic conditions of northeastern Texas.

1. APRIL-MAY. This series is for the most part represented by those hardy Oedipodinae that hibernate as winter juveniles in the area under discussion. There is no uniform life history behavior for the April-May grasshopper fauna as each species has its own distinctive life span. However, there is sufficient uniformity to justify this grouping. The two early spring Arphias illustrate wide contrast in seasonal behavior. *Arphia conspersa* Sc. passes the winter in the fifth instar, reaches adulthood with a bound in late March or early April, and soon disappears. *Arphia simplex* Sc., one of the subdominants of our entire area, is a hardy and vigorous species, and keeps up a fairly long period of adult activity, in part because of a wide-ranging juvenile cycle. The adult peak of *Arphia simplex* Sc. is reached in May and continues through June. The following, listed in order of appearance, may be considered frequent to abundant adult species in the April-May series:

Eritettix simplex (Sc.)
Arphia conspersa Sc.
Chortophaga viridifasciata (DeG)
Psoloessa texana (Sc.)
Melanoplus confusus Sc.
Arphia simplex Sc.
Pardalophora phoenicoptera (Burm.)
Xanthippus corallipes pantherinus (Sc.)
Pardalophora saussurei (Sc.)
Acrolophitus variegatus (Thos.)
Spharagemon collare cristatum Sc.
Melanoplus mexicanus (Sauss.)

2. MAY-JUNE.[8] Outstanding acridian adults of the May-June period are the species that hatch with the warm days of late March and early April.

[8] From the tables it will be noted that certain species terminate their seasonal activity in May while other species reach adult activity during May. It is this sort of overlapping that makes a clear cut chronological grouping impossible.

The juvenile period, therefore, of this series is much shorter than the juvenile period of the over-wintering series of the preceding group. In favorable season, several species in this group are likely to appear in large numbers and may approach destructive proportions, at least as far as range vegetation is concerned. On the whole, however, they are not usually considered of importance as economic species. The more populous May-June acridians are:

Melanoplus texanus (Sc.)
Melanoplus impiger Sc.
Trimerotropis citrina Sc.
Dissosteira carolina (L.)
Paraidemona punctata (Stal.)
Boopedon maculatum Caudell
Dactylotum pictum (Thos.)
Hesperotettix v. viridis (Thos.)
Hesperotettix speciosus (Sc.)
Melanoplus glaucipes (Sc.)
Spharagemon bolli Sc.

3. JUNE-AUGUST. In Colorado (Hebard, '33) and Kansas (Isely, '05, Hebard, '31), where I have especially checked acridian activity, the July-August acridian fauna is the climax fauna of the year for adult grasshopper activity. Within northeastern Texas conditions are somewhat different, and it is a question whether June-August or the preceding May-June group ranks first when it comes to counting the total population of active adult individuals within the area under consideration. For the blackland prairies the Mermirias reach their adult activity during the June-August cycle. The adult activity of *Melanoplus differentialis* (Thos.), the grasshopper of chief economic importance in this area, belongs to the June-August group. Among the Oedipodinae, *Hadrotettix trifasciatus* (Say) is a widely distributed and common representative. The June-August series may be summarized as follows:

Schistocerca lineata Sc.
Ageneotettix deorum (Sc.)
Hadrotettix trifasciatus (Say)
Melanoplus differentialis (Thos.)
Trimerotropis pistrinaria Sauss.
Orphulella speciosa (Sc.)
Melanoplus bispinosus Sc.
Mermiria m. maculipennis Bruner
Melanoplus flabellatus Sc.
Melanoplus p. ponderosus Sc.
Melanoplus discolor (Sc.)
Mermiria neomexicana (Thos.)
Trachyrhachis kiowa fuscifrons (Stal)

4. AUGUST-OCTOBER. A number of acridian species do not reach their adult peak until August. Several of these may be found as juveniles throughout August, but by September acridian juveniles are chiefly those that belong to the small adult October-April group or over-wintering juveniles. *Syrbula admirabilis* Uhler, usually the most generally distributed late summer and fall species throughout this area, is often taken as adult in late July but does not reach its adult numerical climax until August. The August-October group may be tabulated as follows:

Syrbula admirabilis Uhler
Hippiscus rugosus (Sc.)
Dichromorpha viridis (Sc.)
Schistocerca obscura (Fab.)
Melanoplus k. keeleri (Thos.)
Arphia xanthoptera (Burm.)
Campylacantha o. olivacea Sc.
Melanoplus scudderi latus Morse
Encoptolophus sordidus costalis (Sc.)
Encoptolophus subgracilis Caud.
Melanoplus plebejus (Stal)

5. OCTOBER-APRIL. There are four species that typically become adults in late September or October, live a quiescent semi-dormant life most of the time but become active on warm sunny days even in January-February, lay their eggs in April and early May, and then pass from the scene of action. At this season may be mentioned:

Mesochloa abortiva Bruner
Amblytropida occidentalis (Sauss.)
Schistocerca d. damnifica (Sauss.)
Schistocerca a. americana (Drury)[9]

VARIATIONS IN SEASONAL RHYTHM

YEAR AROUND BREEDERS. There are a number of species that have been included in the tables that are of unusual interest when one studies the acridian fauna of northeastern Texas. These species have been designated as year around breeders. It is to be noted, as I have already pointed out, that all of these species have their seasonal climax and reach their populous peak as other species do. However, these year around breeders in northeastern Texas are strikingly different in their life cycle behavior from similar species or subspecies found in Kansas, Colorado, Indiana (Blatchley, '20), New England (Morse, '20), Canada (Criddle, '33), or other northern and eastern areas where acridians have been especially studied. The proof of continuous breeding is shown in the fact that juvenile stages are found throughout the year. Here are included:

Chortophaga viridifasciata (DeG)
Trachyrhachis kiowa fuscifrons (Stal)
Encoptolophus sordidus costalis (Sc.)

Further field work may add to the list. Undoubtedly a checking of the Acrydiinae would include several species of the grouse locusts among these year around breeders. It has not been practicable to check this interesting group of insects seasonally.

SEEMINGLY LONG-LIVED SPECIES.—A study of the tables clearly suggests that certain species have a longer period of activity than others. These in addition to the year around species cited include the following:

Arphia simplex Sc.
Spharagemon collare cristatum (Sc.)
Melanoplus impiger Sc.
Melanoplus m. mexicanus (Sauss.)
Trimerotropis citrina Sc.

In the case of these species the same type of physiological behavior noted under the year-round species is observed, that is to say, there is a wide spread of juveniles and this in part explains the persistence of the species listed as long-lived species. However, it is apparent that certain species are hardier and persist for a longer period than others.

[9] There is a theory that part of the Texas *Schistocerca americana* population is from migratory sources. I have, however, taken juveniles in October and November.

SHORT-LIVED SPECIES.—A study of the tables further reveals that a number of species have apparently a short adult life span. Among these may be listed:

Melanoplus confusus Sc.
Acrolophitus variegatus (Thos.)
Eritettix simplex (Sc.)
Arphia conspersa Sc.

With the exception of *Arphia conspersa* Sc. these species in general appear to be less vigorous than the other more abundant species of the area under consideration. However, in the case of *Melanoplus confusus* Sc. and *Acrolophitus variegatus* (Thos.) the passing of specific food plants may account for decrease in numbers, rather than species' vigor. In the main, however, as already indicated, seasonal sequence is the general rule, and each of the five periods as outlined has certain dominant species that belong primarily to the time of the year under which the various seasonal groups are listed.

SPECIES NOT INCLUDED IN THE TABLES

DISCONTINUOUS DISTRIBUTION.—There are several other fairly common species that might have been included in the Tables 1-3, but on account of discontinuous distribution these species were not at our chief study stations and on this account were difficult for year around checking. However, as they appear in good numbers in their favorable localities it will make the presentation of this study of northeastern Texas acridian fauna a little more complete if the species cited below and their seasonal and soil relations data are added to the fifty-one species listed in the tables. Here may be included:

Paratettix cucullatus cucullatus (Burm.)—year around Table 3.
Tettigidea lateralis lateralis (Say)—year around, Table 3.
Syrbula fuscovittata (Thos.)—August-October, Table 3.
Orphulella pelidna (Burm.)—August-October, Table 2.
Psinidia fenestralis fenestralis Stal.—long-lived species, Table 2.
Boopedon auriventris McNeill—May-June, Table 1.
Hesperotettix viridis pratensis (Sc.)—May-June, Table 1.

POPULATIONS

Population figures must always be in the forefront of animal community studies (Elton, '27; Shelford, '29). How to arrive at accurate or even fairly accurate approximation of numbers per unit area or the comparative frequency of the several species making up the population in a given habitat of highly motile and elusive acridians is admittedly difficult (Uvarov, '28, Criddle, '33). For species of economic importance counts after poisoning appear at first to be absolute, but even here economic entomologists find that species' reactions to baits vary widely and even the poison count fails where a considerable number of species are present on the same plot.

In making quantitative acridian field studies in such a region as northeastern Texas the plot, tract, and area for specific studies is likely to be as

variable as are the species themselves. Smooth, level prairies; rough, rugged, almost inaccessible bad lands; weedy tracts covered with spiny ball nettles (*Jatropha stimulos* Michx.) and sticky sand burrs (*Cenchrus pauciflorus* Benth.); marshy flats covered with tall grasses, rushes, and willows; timber margins and open woods with tangled growths of weeds and shrubbery—these and many others are typical habitat areas well known to all field students of terrestrial animals. It should be clear from the foregoing that not only many species but particular habitats need specific quantitative enumeration methods.

Whatever may be the methods used in enumerating acridian populations, the writer is thoroughly convinced that an intimate acquaintance of the habits of the species, a knowledge of their seasonal behavior, life histories, and local distribution are greater aids in the determination of the acridian populations than any technique of capturing or counting with which he is acquainted.

As will be evident after understanding the methods of census taking, the totals in the last column in the tables (Tables 1-3) are of more significance than first appears. They represent the total number of specimens of each species that have been checked in the census counts made at the various stations during the past six years. It stands to reason that the really abundant species usually have been checked by sample specimens, while the less numerous species in the tables, those that fall into the occasional to frequent classes, may show all of the specimens actually seen or taken by net. Species showing records of less than 100 in the last column in the tables are the less frequent species of the central area studied. Species showing as many as 200 or more records could without doubt have been taken during the period of the writer's studies much more frequently than the number of times they are recorded.

METHODS OF CENSUS TAKING

In judging the frequency of a single species in a given type of habitat or in the study of its seasonal variation—increase, peak, or decrease as indicated in Tables 1-3—two methods have been employed.

(1) SINGLE SPECIES ENUMERATION.—The entire attention in this case is centered on the relative frequency of a single species. This method has been employed especially for large, active, easily recognized, high flying species as *Xanthippus c. pantherinus* (Sc.), *Schistocerca a. americana* (Drury), *Hadrotettix trifasciatus* (Say), *Acrolophitus variegatus* (Thos.), and many others. Sight counts have been combined with *net records* of the species being enumerated in order to check its frequency in a given type of habitat or on a given date of its adult seasonal activity.

(2) MASS COLLECTING OR AGGREGATE SPECIES ENUMERATION.—This method has been employed for the smaller, low flying acridians, short-winged

species, and sometimes for species in late instar juveniles. For these smaller species sweeping methods were combined with watching for and collecting individual specimens. This method has been found helpful in estimating the frequency of the different species within the general acridian population. Mass collecting is essentially obligatory where three or more species of these smaller acridians become frequent to abundant in the same habitat. The first method was used in preference when species and individuals were not numerous. Mass collecting has worked fairly well with such species as *Hesperotettix v. viridis* (Thos.), *Melanoplus impiger* Sc., *Hesperotettix speciosus* (Sc.), *Ageneotettix deorum* (Sc.), and many others.

ENUMERATION TECHNIQUE

In an effort to make clear the techniques of the foregoing methods an outline of procedure is given:

HABITAT.—Population enumerations all refer to uniform types of habitat. Homogeneity of the habitat has been the standard for limiting the area to be studied rather than a fixed unit area. Recent workers have used fixed areas of so many square meters (Gause, '30), fractional parts of an acre (Diver and Diver, '34), specific routine sweeps (Gray and Treloar, '33), and time observation index (Lean, '36).

TIME UNIT.—It was found that for seasonal check-ups half an hour usually gave sufficient time for census taking. Thirty minutes, therefore, was fixed as a standard time unit in using either method of census taking.

COMMON.—The term common was selected as the standard frequency term. Species more numerous than common were designated as abundant or swarming; less numerous than common were designated as frequent, occasional, infrequent, rare. The value of *common* is indicated as the checking of thirty specimens of a species by *single species enumeration* in the standard unit of time, or in other words, a time average of one specimen a minute.

ADULTS AND JUVENILES.—For many of the species in this area the juveniles were definitely known from the first instar. However, in several species the juveniles could not always be identified with certainty. Juveniles, for this reason, were not checked in frequency enumeration. It should also be remembered that in several species juveniles were undoubtedly present although overlooked or not recognized especially in early instars. This will explain why juveniles are sometimes not indicated in a table until the fourth or fifth instar stages were taken. In certain of the species, therefore, juveniles if recognized would undoubtedly have shown earlier than they are indicated in Tables 1-3.

SINGLE SPECIES ENUMERATION FREQUENCY TERMS

The approximate numerical value of the different frequency terms used in Tables 1-3 as used in single species enumeration may be defined as follows:

Frequency Terms	*No. of Specimens Checked in Half an Hour.*	
Swarming	Over 100	
Abundant	50-80	
Common	25-30	
Frequent	10-12	
Occasional	2-3	
Infrequent	1	Infrequent species are not taken regularly even at typical stations.
Rare		1 or 2 individuals for the season or several seasons.
Juveniles		This indicates the absence of adults and the presence of recognized juveniles.

These terms may be conveniently modified, and in the field records may read occasional to frequent, frequent to common, common to abundant, etc., if the number of specimens falls between two categories as defined above.

For the benefit of other workers dealing with grasshopper populations who may wish to try out the *time unit method* as here proposed, somewhat more detail as to the routine of transforming mass counts to the same standards of frequency as individual counts is added.

TRANSFORMATION OF MASS COUNTS INTO SINGLE SPECIES EQUIVALENTS

In mass collecting more chance specimens are taken than in individual species collecting. Furthermore, as a rule, the smaller acridian species are usually more numerous than the larger highflying species. Chiefly by trial and error it has been found that to divide the *mass-census-numbers by two* or to reduce the mass count by one-half will help to equalize the results of the two methods. In other words, the individual species numbers of mass count collecting are reduced fifty per cent when transformed into single species equivalents. The frequency terms used have the same numerical value as in single species enumeration.

Therefore, in enumerating mass counts the first step is to sort out and count the numbers of each of the individual species making up the aggregate grasshopper population taken in a standard unit of time. Second, a total of the more frequent species, that is, those that are found to be sufficiently numerous to rate above *occasional,* is noted from the count made in step one. This total number of the more frequent species is used as a divisor of the time employed (thirty or sixty minutes or longer) in making the aggregate species collection. The quotient of this division will give the time in minutes to be allotted to each of the common species to be transformed from aggregate species to individual species frequency standards as outlined above.

A hypothetical case may serve to clear up the details of the transformation of mass counts into single species equivalents. A single worker in thirty minutes collects chiefly by sweeping and watching for known species from a uniform habitat a total of 95 grasshoppers representing eleven species. A sorting of the eleven species making up the aggregate-species-catch

results as follows: (1) 40 individuals, (2) 20, (3) 10, (4) 8, (5) 6, (6) 4. These six species are singled out as the more common species as the five remaining species representing a total of 7 individuals may be assigned to the *infrequent* and *occasional* groups. Giving attention now to the six most abundant species it is found that by dividing 30 minutes by the total species number which is six, our *time unit* is found to be five minutes or one-sixth of our standard individual species unit. Transformation is completed and frequency calculated by further division of mass numbers by 2 and multiplying the figure obtained for each species by six, the number needed to bring the time allotted to each abundant species to a total of thirty minutes, the *standard time unit*. The calculated frequency for the above species group would be as follows: (1) 40 divided by 2, times 6, gives 120 and would be designated as swarming; by the same process the remainder of the series will rate (2) 60, abundant; (3) 30, common; (4) 24, common; (5) 18, frequent to common; (6) 12, frequent.

The described routine doubtless appears rather complicated. In fact, however, the experienced worker with acridian populations may in most cases approximate frequency facts by inspection.

To summarize, the writer finds that a knowledge of the species in the habitat being studied with an understanding of their behavior will permit the census taker with the foregoing census methods, single species and mass count enumeration to arrive at fairly accurate *comparative acridian seasonal and species populations*. These frequency numbers are represented by *frequency terms* and by totals given in Tables 1-3.

GENERAL DISCUSSION

Acridian seasonal communities are chiefly correlated with climatological changes. In northeastern Texas the non-frost season is eight months (Carter, '31, pp. 12-13; Weather Bureau, '31). This growing period gives time for wider ranges in temperature, humidity, aridity, and the constant changes and variations in plant and animal activities. As a direct result, there is a larger and more clearly defined succession of seasonal biotic communities.

The seasonal passing of specific food plants is definitely correlated with the disappearance of certain acridian species. The most obvious case is the decrease of *Acrolophitus variegatus* (Thos.) with the passing of *Filago nivea* Small (Indian tobacco). *Melanoplus texanus* (Sc.) fades from an abundant to occasional acridian along with the disappearance of the Indian daisy, *Gaillardia pulchella* Foug. The yellow wingless *Paraidemona punctata* (Stal) is definitely associated with *Thelesperma trifidum* (Poir.) Britton (Black-eyed Susan) and its yellow sap. Lingering patches of *T. trifidum* (Poir.) Britton mark the last stand of frequent representatives of *P. punctata* (Stal). There are other less evident cases of close association of specific plant species and acridian species, and these correlated plant and animal species march together or disappear with the shifting of the seasonal parade.

The extreme and extended severe drouth of the summer of 1934 resulted not only in the drying up and rapid passing of the plant species needed for acridian food or shelter but also in a consequent and rapid decrease in acridian populations. At upland stations this markedly unfavorable season resulted in the early disappearance of acridians along with their associated plants.

Even in favorable years many of more abundant grasshopper species of northeastern Texas have a comparatively short adult peak—four to six weeks on the average. This short period of acridian adult activity holds especially for the shallow soil species (Table 1). In some cases, however, environmental pressure is matched by a greater species resistance as witnessed in the long adult seasonal persistance of *Trachyrachis kiowa fuscifrons* (Stal) and *Trimerotropis pistrinaria* Sauss.

The open field grasshopper species of our light sandy soil stations (Table 2), while rather limited in the number of acridian species as well as the plant species, have a longer sustained adult peak than the average run of species at the shallow soil stations (Table 1). These relationships may be verified by comparing *Melanoplus impiger* Sc., *Spharagemon collare cristatum* (Sc.), and *Pardalophora saussurei* (Sc.) (Table 2) with related shallow soil species *Xanthippus corallipes pantherinus* (Sc.), *Melanoplus confusus* Sc., and *Melanoplus texanus* (Sc.) (Table 1). The explanation lies in the greater plant stability of the light sandy soil areas.

The timber margin, open woods, and thicket acridians are primarily a late fall-winter, early spring fauna (October-April). They have shelter when protection is needed against occasional wintry blasts, and periodic warmth and winter sunshine made possible by the absence of foliage of broad-leaved plants. *Spharagemon bolli* Sc., however, is exceptional as it does not become adult until late June. The wide range of seasonal adaptiveness in grasshoppers, limited always by suitable temperature, aridity, and sunshine, is extended by an apparently made to order seasonally adjusted acridian fauna for each and every clearly defined habitat.

REGIONAL DISTRIBUTION WITHIN NORTHEASTERN TEXAS

Regional distribution as here presented is based chiefly on my personal field records. With the exception of scattered references to individual species and the writer's previous studies (Isely, '34), Rehn's ('19) researches of the Mermirias are the only records of acridian distribution within northeastern Texas that have been published.

Hebard's ('31) tabulations of acridian distribution as given in his Orthoptera of Kansas have been of the greatest value in the study of the northeastern Texas area. The researches by Morse ('04, '07) dealing with acridians in the southeastern United States and the Texas Panhandle, by Blatch-

ley ('20) in northeastern United States, and Little's ('26) studies in Brazos County, Texas, give species records that have been helpful in checking acridian distribution within northeastern Texas.

EAST-WEST DISTRIBUTION

As the field worker checks with some detail the local acridian faunas east and west across northeastern Texas, he finds a striking correlation between rainfall records and acridian regional distribution. Study stations near Palo Pinto, Mineral Wells, Glen Rose, and Cleburne on the western border of the area studied have several species not taken at the stations in the blackland

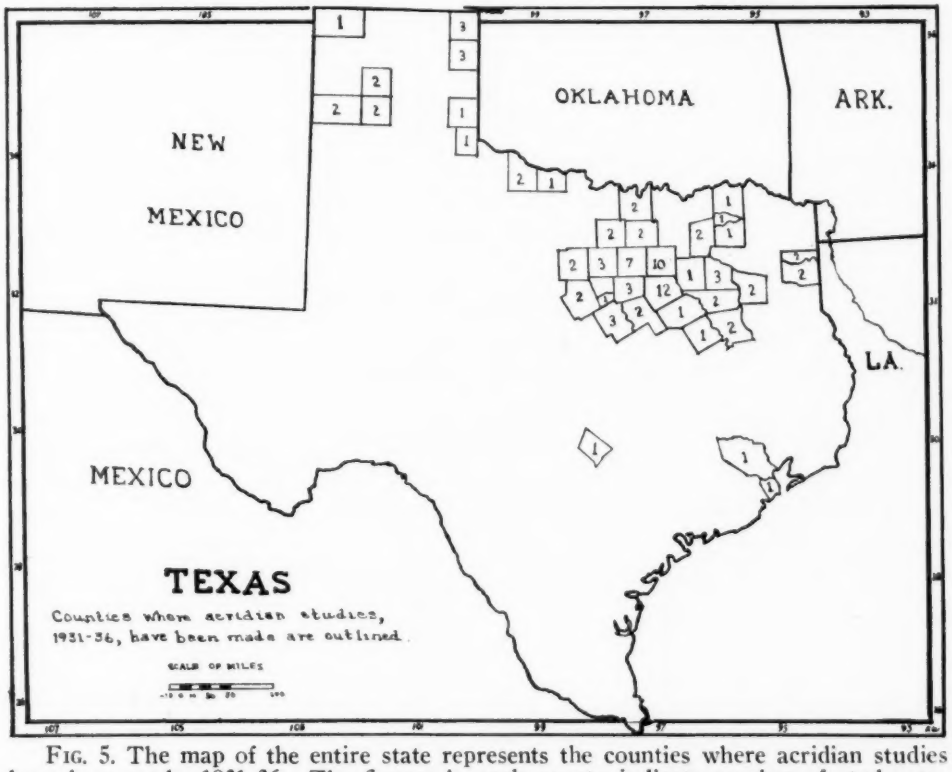

FIG. 5. The map of the entire state represents the counties where acridian studies have been made, 1931-36. The figures in each county indicate number of study stations; e. g., Ellis, 12; Dallas, 10; Tarrant, 7; etc. Acridians of the Pan-handle of Texas are taken into account only in so far as they suggest the affinities of certain of the great plains grasshoppers.

prairie belt near Waxahachie or Dallas, while other species listed as infrequent or rare for Ellis and Dallas Counties become frequent to common in Palo Pinto County. On the other hand, acridian assemblages from near Tyler, Elkhart, and Marshall on the eastern border are distinctive when compared with acridian faunas of the other belts. Accordingly, from the regional viewpoint, there are three more or less distinctive east to west acridian faunal belts within northeastern Texas which correspond to and parallel in part combinations of the five floral and soil belts which have been outlined (Carter, '31) by those who have studied plant and soil relations in

northeastern Texas. The area and boundaries of the floral-soil belts are shown on the map of northeastern Texas in Figure 1.

The blackland prairie belt, especially along its western margin, serves as a delimiting belt between the plains and the grand prairie faunas, while the eastern margin of the blackland prairie belt marks the extreme westward advance of a number of species that belong typically to the southeastern acridian faunas of the United States. While each species has its distinctive limitations, certain species apparently limited by similar controlling environmental factors may be grouped together.

GREAT PLAINS SPECIES

A number of great plains species enumerated below have become fairly well established in the west cross timbers and grand prairies and find their way eastward sparingly into the blackland prairie belt. The frequency of these species in the blackland prairie belt based on six years of field study in Ellis and Dallas Counties is indicated by the following observations: *Opeia obscura* (Thos.), occasional; *Amphitornus coloradus* (Thos.), occasional; *Aulocara elliotti* (Thos.), infrequent; *Syrbula fuscovittata* (Thos.), frequent (only in one locality); *Spharagemon equale* (Say), frequent; *Platylactista aztecus* (Sauss.), occasional; *Trimerotropis p. pallidipennis* (Burm.), rare; *Brachystola magna* (Girard), rare; *Hypochlora alba* (Dodge), occasional; *Melanoplus packardii* Sc., occasional; *Phoetaliotes nebrascensis* (Thos.), rare. In addition to these, the following species not taken in the blackland prairies have been found in the grand prairies and in the west cross timbers at stations in Palo Pinto, southwest Johnson, and Bosque Counties, that is to say, on the west border of the blackland prairies: *Boopedon nubilum* (Say), frequent; *Rehnita capito* (Stal), frequent; *Trimerotropis saxatilis* McNeill, frequent; *Leprus cyaneus* Cockerell, rare; *Melanoplus lakinus* (Sc.), rare. All of these with the exception of *T. saxatilis* McNeill, belong to the acridian fauna of the great plains and are typically western, northwestern and southwestern species.

EASTERN AND SOUTHEASTERN SPECIES

The following species while belonging primarily to the fauna of the east and southeast have been taken in their restricted habitats in a few localities in the blackland prairie belt and the east cross timbers: *Orphulella pelidna* (Burm.), common; *Psinidia f. fenestralis* Stäl, frequent; *Leptysma marginicollis* Serv., infrequent; *Hesperotettix viridis pratensis* (Sc.), frequent; *Boopedon auriventris* McNeill, common in one localty.

The following eastern and southeastern species have not been taken in the blackland prairie belt or even in the east cross timbers, but are found as important species of the east Texas timbers in the vicinities of Elkhart and Tyler in Anderson and Smith Counties: *Tryxalis brevicornis* (Johann), common; *Mermiria picta* (Walker), common; *Romalea microptera* (Beau-

vois), common; *Schistocerca alutacea* (Harris), occasional; *Paroxya a. atlantica* Sc., occasional; *Melanoplus angularis* Little, rare. Further study may show that these reach westward to the line separating the blackland prairies from the east Texas timbers.

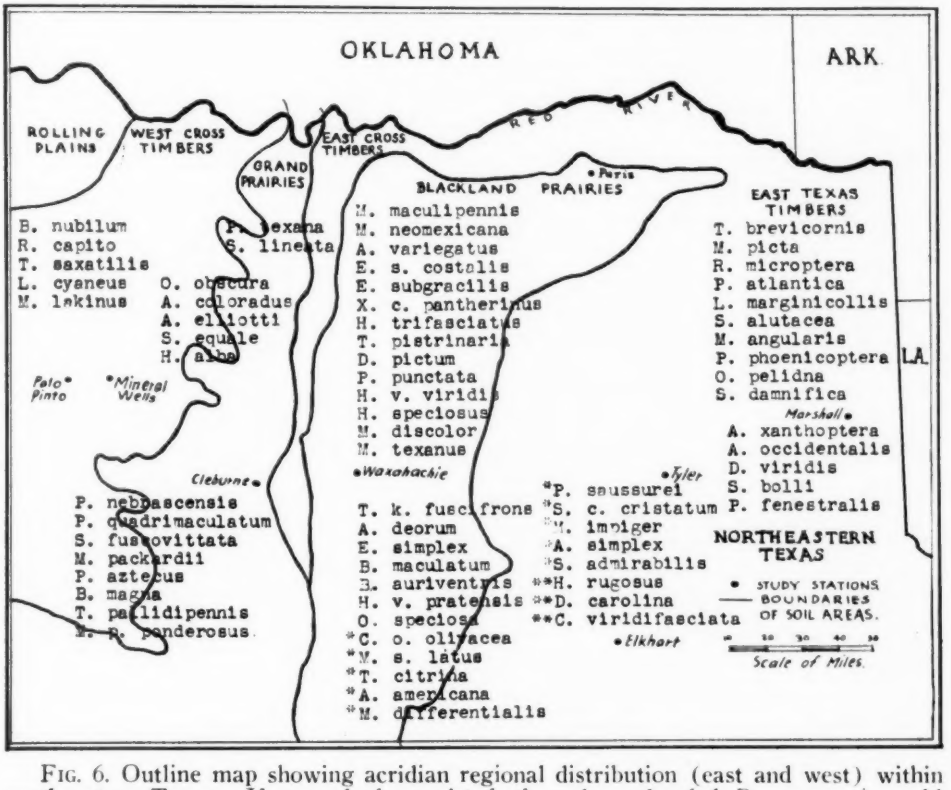

FIG. 6. Outline map showing acridian regional distribution (east and west) within northeastern Texas. If space had permitted, the column headed *P. saussurei* would have followed *M. differentialis.*

These facts of east-west distribution are more satisfactorily presented in Figure 6. On the map, in addition to the species listed previously in this section—regional distribution—which are primarily either western acridians working eastward (grand prairie and west cross timber species) or eastern species reaching westward (east Texas timber species), are added the outstanding representatives of the species that have been studied in the central area of the blackland prairies and east cross timbers.

In the central column on the map (Fig. 6) all of the species above *Ageneotettix deorum* (Sc.) (inclusive) are primarily plains, western, north central and south plains species while the ones that follow are for the most part southern and eastern, the species double starred being of wide general distribution. Single starred species are found throughout northeastern Texas (Hebard, '31, pp. 220-227).

If the writer's field records may be taken as sufficient criteria, there is a considerable variation in the density of acridian populations in the several

soil-vegetation belts of northeastern Texas. The series arranged in ascending order from the least to the most populous will be as follows: (1) east Texas cross timbers; (2) east Texas timbers; (3) west Texas cross timbers; (4) blackland prairies; (5) grand prairies. The acridian population at the grand prairie stations, as studied in west Tarrant and southwest Johnson Counties in June, July, and August during several seasons, clearly point to the grand prairie belt as the optimum acridian area both in number of acridian species and in aggregate density among the five belts crossing northeastern Texas.

A two-day survey trip was undertaken July 3-4, 1935, into the extreme eastern tip of the blackland prairie belt. Collections were made in Hunt, Delta, and Lamar Counties, Paris in Lamar County. These are the most easterly blackland prairie stations. This reconnaissance survey clearly suggested that, while many of the blackland prairie acridian species were following the eastward extension of the calcareous soils, other grasshopper species of the blackland prairies were absent or present in smaller numbers in the narrow black prairie extension into the east Texas timbers belt. In a similar manner, the east Texas acridian fauna, though always less numerous in total species than the blackland prairie grasshoppers, also showed a smaller number of typical sandy soil species in the more westerly narrow strip of the east cross timbers than in the more extensive and contiguous east Texas timber area. My records at the east cross timber stations check five species less than the number that were taken at the east Texas timber stations. Only two species of apparently western origin, *Schistocerca lineata* Sc. and *Psoloessa texana texana* Sc. were taken at study stations in the east cross timbers. *Schistocerca lineata* Sc. was not found at stations in Van Zandt, Smith, Anderson, and other east Texas timber counties. *Psoloessa texana texana* (Sc.), however, was taken on the extreme east Texas border in Marion County.

FACTORS DETERMINING DISTRIBUTION

The environmental factors controlling the distribution of terrestrial animals in such an area as northeastern Texas are many. These terrestrial factors are typical of similar continental areas. Their extreme variations, separately and collectively as well as their influences upon plant and animal life, have been studied by leading ecologists in America and Europe; however, only a beginning has been made in analyzing terrestrial environmental complexes.

The environmental factors that play a leading rôle in the acridian distribution as well as all terrestrial organisms doubtless are climate, soil, topography, altitude, geographical position, and biotic relationships. In this discussion we are not taking into account geological history but only present day conditions. Among the environmental factors climate embracing as it does temperature, rainfall, pressure, wind velocity, sunshine, and con-

sequent humidity, evaporation rate, moisture, etc.,—climate is doubtless of primary importance. The climatological studies of the United States Weather Service supply us with significant records for rainfall and temperature. These records show minimum, mean, maximum, daily, monthly, and annual variations. The average temperature records for northeastern Texas are fairly uniform for the entire area, and it would appear that the general temperature records are not significant in determining general regional distribution. The rainfall records, however, show marked differences ranging as shown on the map, Figure 6, from 45 inches annual average in the eastern part of our area to 30 inches in the western part. The correlation of rainfall with humidity, rate of evaporation, moisture, growth of vegetation, is obvious. The temperature within the micro-climates of freely motile insects such as acridians is also an evident factor.

Among the factors controlling local distribution of grasshoppers, soil, topography, and consequent vegetation for food and shelter are important, but as far as regional distribution is concerned these are not as important as are the climatological factors enumerated below.

To summarize, we would conclude that as far as we have data at present rainfall, available water supply (McBryde, '33), wind velocity, and sunshine as they are related to soil, soil moisture (Strohecker, '37), plant life, and other biotic relationships are the factors that must be analyzed in seeking an explanation of the acridian faunal belts as found in northeastern Texas. Further study of ecoclimates (Uvarov, '31) and micro-climates will have to be made before one can draw more precise conclusions.

NORTH-SOUTH DISTRIBUTION

In contrast with the well defined regional belts that mark the east and west distribution in northeastern Texas, north and south differences in the area studied are comparatively slight. This serves further to emphasize the marked reactions of northeastern Texas acridians to the seemingly slight but effectual east and west climatic differences. It is an interesting fact that those well known north ranging and much studied economic species, *Melanoplus mexicanus mexicanus* (Sauss.) and *Melanoplus bivittatus* Say, have scarcely been able to maintain their meager foothold as representative acridians in northeastern Texas during the six years that the writer's investigations have been in progress, while *Melanoplus femur-rubrum* (DeGeer) has fallen into the rare classification from the viewpoint of numbers. At Galveston, Texas, (VII., 4, '36) I found *Melanoplus femur-rubrum* (DeGeer) common. In the same way *Dissosteira carolina* (L.), *Arphia xanthoptera* (Burm.), and *Spharagemon bolli* Sc., widely distributed and well known species of the North and East, have maintained a meager existence in northeastern Texas during the period of these studies, and in Tables 1-3 are listed as occasional.

SUMMARY

This paper deals with an inquiry as to the relative importance of the several environmental factors that play a part in determining the acridian distribution, both local and regional, in northeastern Texas. It further seeks to throw light upon the inter-relations and reactions of acridians to variations in climate, soils, topography, and biota.

I. SEASONAL SUCCESSION.

Acridian seasonal succession is determined in some instances by specific food plants but chiefly is determined by inter-relations resulting from vegetational cover and climate.

1. Species hibernating as adults are usually found in the open woods or heavy cover of shrubs or coarse grasses.

2. Species hibernating as juveniles are associated either with timber margins and open shrub cover or are found on eroded slopes.

3. Campestrian species of the prairies, level meadows, or open parks more frequently hatch in the spring and reach their adult peak in midsummer.

4. Late summer and fall adults are chiefly of wide distribution, both locally and regionally, and are often associated with coarse, xeric vegetation.

II. POPULATIONS AND SPECIES.

Dominant acridian species (abundant species) within the central area (Fig. 1) are characteristically Texan and may have originated in central Texas as Rehn suggests for the Mermirias (Rehn, '19) or are derived chiefly from the acridian faunas of the southeast, south, or southwest.

III. SOIL RELATIONS.

Soils and their related vegetation used as food or shelter appear to be primary factors in determining local acridian communities and the microclimate of specific habitats.

IV. REGIONAL DISTRIBUTION.

Since broadly considered, topography, altitude, temperature, and pressure are essentially similar in all of the general habitats (stations) herein reported, Regional Distribution can best be understood by taking into account differences in rainfall, wind velocity, evaporation, relative humidity, soil differences, plant differences and the consequent micro-climates and ecoclimates of the restricted habitats of the three regional belts (Fig. 6); (1) east Texas timber acridians and east cross timbers, (2) blackland prairie acridians, and (3) grand prairie and west cross-timber acridians. Micro-climate is undoubtedly dominant in marking out specific habitat differences and in determining restricted acridian communities but secondary to the broader climatological influences when joined with biotic and physiographic interrelations that are primary in determining regional distribution of acridians within northeastern Texas.

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ECOLOGICAL STUDIES ON THE CANADIAN RIVER FLOODPLAIN IN CLEVELAND COUNTY, OKLAHOMA

By

HAROLD M. HEFLEY

Norman, Oklahoma

A thesis, submitted to the Faculty of the Graduate School, University of Oklahoma in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1935.

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ECOLOGICAL STUDIES ON THE CANADIAN RIVER FLOODPLAIN IN CLEVELAND COUNTY, OKLAHOMA*

INTRODUCTION

Most investigations of succession and population fluctuations of communities have been concerned chiefly with the uplands. The chief studies of river floodplain succession in North America are those of Tharp (Selards, Tharp, and Hill 1923), and Barclay (Harriet George 1924). Some work has been done in Russia on the Kama River floodplain (Baskina and Friedman 1926: Beklemischev, 1928), but these authors worked with only a few stations, and drew but a few general conclusions.

The floodplain of the Canadian River is a fruitful field for ecological study for the writer since he has had an intimate acquaintance with it since childhood days. Probably no more ecologically dynamic region exists: the seasonal, diurnal, and yearly fluctuations of meteorological factors are great and sudden; the course of the river changes with each succeeding rain and the shifting sand of the lower levels is constantly being moved by wind and water. Such conditions cause the initial communities in the floodplain sere to be distinctly defined.

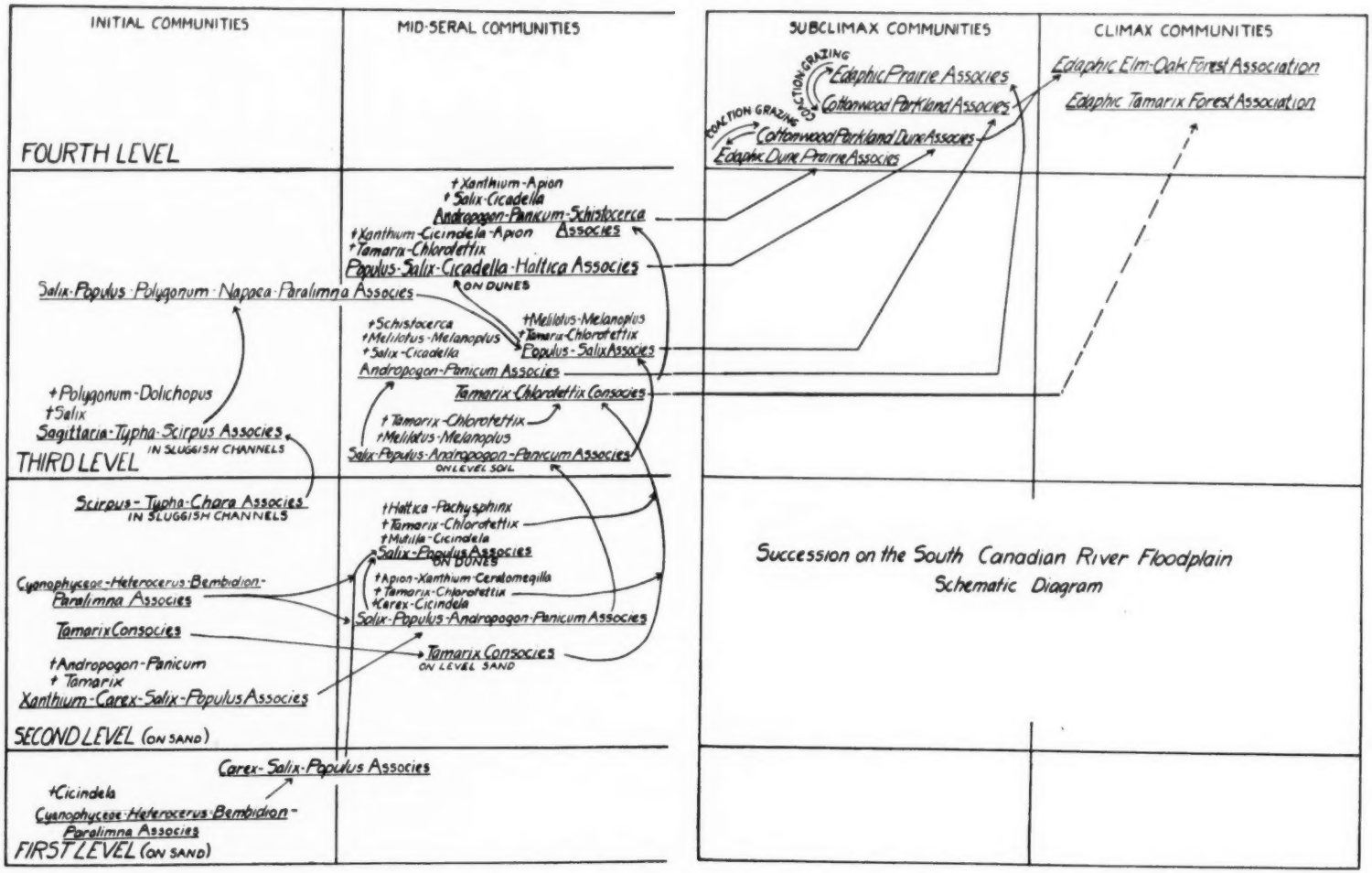
Three groups of collecting stations were set up on the floodplain and studied intensively from September, 1933, until October, 1934. The data obtained form the basis for the population studies. Observations made by the writer and others during the past two decades or so are the materials on which the remainder of the discussion is based.

One group of stations (Nos. 10, 13, 16, 17, 18, 19, 20, 21) was located in Township 9, Range 3 west of the Indian Meridian, in a portion of the floodplain known locally as the Ten Mile Flat. Another group (Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 14) was located in Township 8, Range 3 west, near the Norman Bridge, three miles southwest of the University of Oklahoma campus. A third group (Nos. 12, 15, 22) was located in Township 8, Range 2 west, approximately two miles south of the campus. In addition to work at these stations, cruising trips were made throughout the floodplain from a line west of Noble, Oklahoma, to the Newcastle Bridge, situated in the southwest corner of Township 10, Range 3 west, a distance of approximately 15 miles. Of the above stations, Nos. 11, 12, 14, 15, 16, 18, 19, 21 and 22 were selected for quantitative seasonal fluctuation studies of insect populations.

Geologic and Physiographic History

There has been no detailed work on the geology of the portion of the floodplain studied, and the physiography has been but little investigated

* Contribution from the Department of Zoology, University of Oklahoma, N. S. No. 145.


INITIAL COMMUNITIES
MID-SERAL COMMUNITIES
SUBCLIMAX COMMUNITIES
CLIMAX COMMUNITIES
FOURTH LEVEL
THIRD LEVEL
SECOND LEVEL (ON SAND)
FIRST LEVEL (ON SAND)
REACTION GRAZING
REACTION GRAZING
Edaphic Prairie Associes
Cottonwood Parkland Associes
Cottonwood Parkland Dune Associes
Edaphic Dune Prairie Associes
Edaphic Elm-Oak Forest Association
Edaphic Tamarix Forest Association
†Xanthium-Apion
†Salix-Cicadella
Andropogon-Panicum-Schistocerca Associes
†Xanthium-Cicindela-Apion
†Tamarix-Chlorotettix
Populus-Salix-Cicadella-Haltica Associes
ON DUNES
Salix-Populus-Polygonum-Napaea-Paralimna Associes
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†Melilotus-Melanoplus
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Andropogon-Panicum Associes
Tamarix-Chlorotettix Consocies
†Polygonum-Dolichopus
†Salix
Sagittaria-Typha-Scirpus Associes
IN SLUGGISH CHANNELS
†Tamarix-Chlorotettix
†Melilotus-Melanoplus
Salix-Populus-Andropogon-Panicum Associes
ON LEVEL SOIL
Succession on the South Canadian River Floodplain
Schematic Diagram
Scirpus-Typha-Chara Associes
IN SLUGGISH CHANNELS
†Haltica-Pachysphinx
†Tamarix-Chlorotettix
†Mutila-Cicindela
Salix-Populus Associes
ON DUNES
Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes
†Apion-Xanthium-Ceratomegilla
†Tamarix-Chlorotettix
†Carex-Cicindela
Tamarix Consocies
Salix-Populus-Andropogon-Panicum Associes
Tamarix Consocies
ON LEVEL SAND
†Andropogon-Panicum
†Tamarix
Xanthium-Carex-Salix-Populus Associes
Carex-Salix-Populus Associes
†Cicindela
Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes

FIGURE 1

(Evans, 1923, Bollinger, 1923). The floodplain varies between one and five miles in width, and is essentially a broad valley with reworked Permian (Pleistocene) and possibly Tertiary soils on its northeastern edge, and Permian soils on its southwestern boundary. Since Pleistocene times, at any rate, the river has degraded, but is aggrading at the present time. These processes have resulted in the formation of benches, or levels. The age of the lower three is known, but that of the fourth is problematical.

Evans, 1923, noted that the third level is formed both by water and wind action, which fact has been verified by the writer during the past 15 years. This level has been raised from one to three meters above its former level by wind action alone during this period.

Sears and Couch, 1935, have made interesting studies of the stratification of soils on river terraces of the fourth level. The river has been cutting down from this level since its formation, according to their hypothesis. There are four distinct humus layers, between which lighter colored layers are interpolated. These authors believe the darker layers to be correlated with more humid climates with greater ground cover and less water and wind erosion, while the lighter colored layers are due to dryer intervals of lessened ground cover and a corresponding increased movement of materials from the upland. The writer is inclined to this interpretation of these layers composing portions of the fourth level, but a great deal more work is needed before their exact nature can be definitely stated.

PHYSIOGRAPHIC SUCCESSION

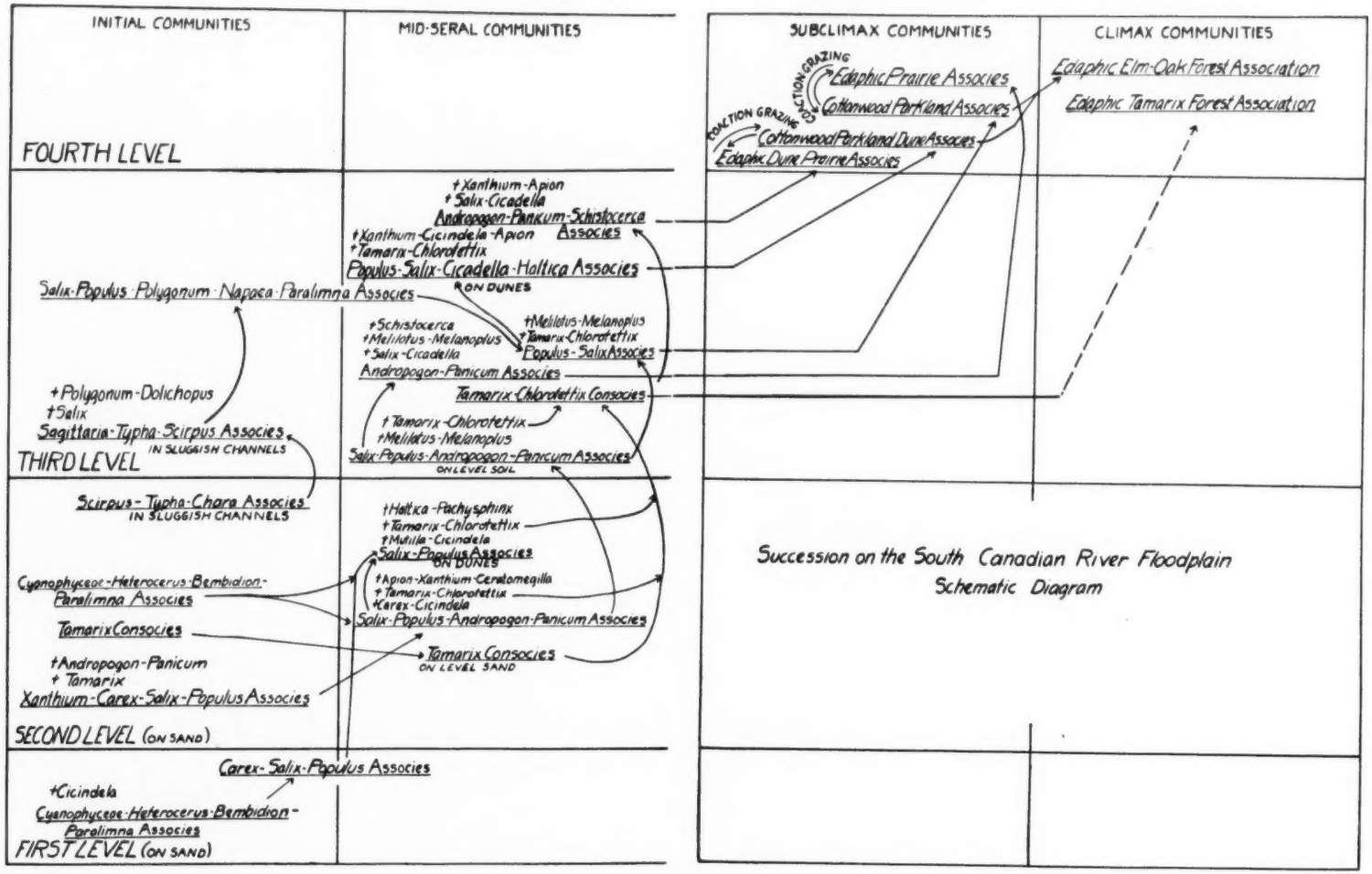
(Figs. 2 and 3)

The river has aggraded in the past and more recently degraded, and at the present time it is again aggrading. This behavior would account for the presence of the bed, and undisturbed portions of the fourth level, but does not explain the presence of the intermediate levels, and the more recent portions of the fourth level. Neither does it account for the presence of the dune ridges which occur at the third and fourth levels on the northeastern side of the floodplain.

These topographic features are caused by wind action, since the prevailing winds are from the south and southwest. Corresponding levels on the southwestern side of the river are somewhat lower and narrower, and the river is apparently migrating in a southwesterly direction.

THE FIRST LEVEL.—This level is physiographically the youngest portion of the floodplain. It is made up of the shallow bed of the river, and low bars immediately adjacent to the bed. It is composed of silt and sand which is in a saturated condition (quicksand) except during the hotter portions of the year when surface flowage stops.

THE SECOND LEVEL.—The second level is formed in large part by the deposition of wind blown sand on the wet river bed after the surface water


INITIAL COMMUNITIES
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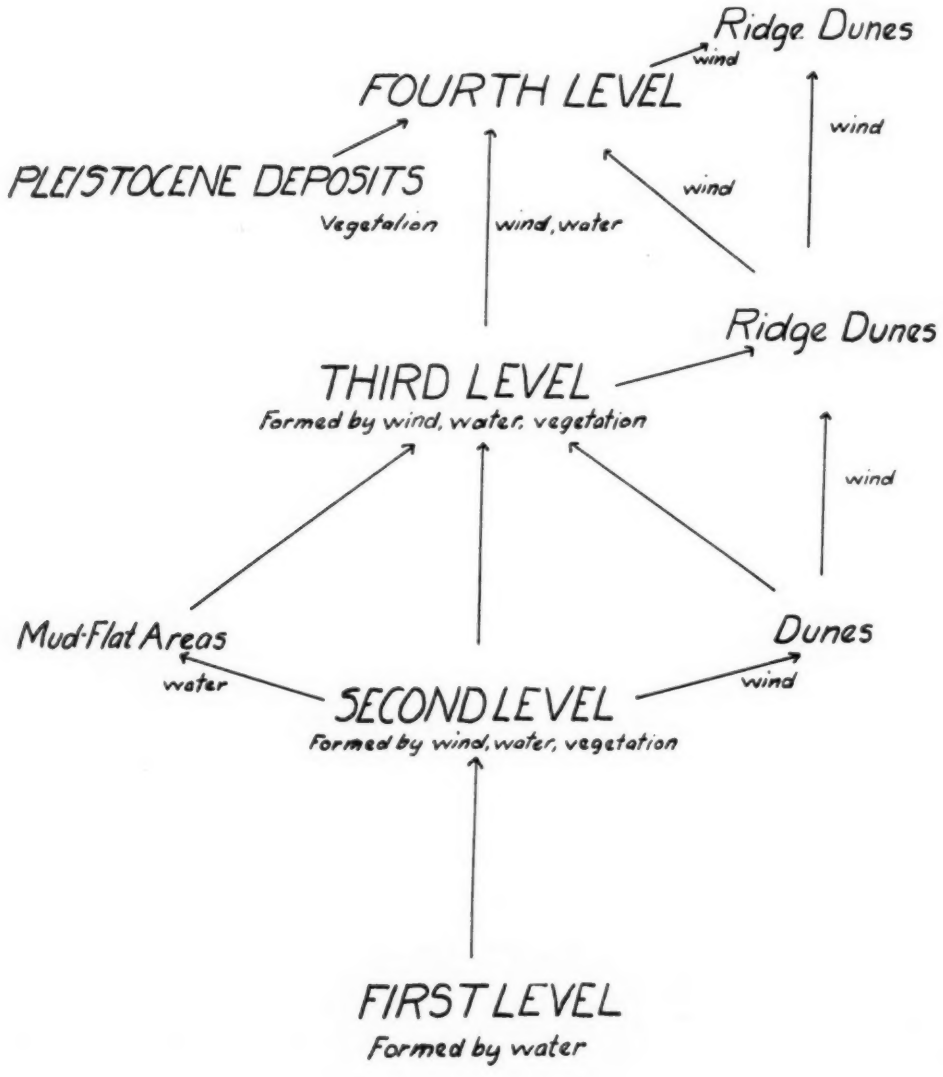

Physiographic Succession on the South Canadian River Floodplain

FIGURE 2

disappears. During a year the level may be raised more than a meter by aeolian action alone.

When small floods inundate the second level and the volume of water is not large enough to produce much cutting, sand and fine silty clay are deposited. During such floods the water cuts secondary channels through the second level, and during ebb stage largely fills these channels with mud. Thus there are two types of substrata on the second level; sand mainly of aeolian origin, and mud of fluvial origin.

Dunes are formed on the second level by sand collecting around clumps and patches of vegetation. These dunes are temporary, and when an area has remained undisturbed long enough for continued sand deposition to cause it to approach third level height, the dunes largely disappear.

THE THIRD LEVEL.—This portion of the floodplain is from one to three meters higher than the second level, and is formed from the latter mainly by the deposition of wind blown sand. As the height of the second level increases grasses become increasingly abundant, and there is a more or less homogeneously distributed vegetational cover. This in turn causes wind borne material to lodge more evenly over the area except at the junction of the second and third levels. More sand, drifting a meter or two above the second level and composed of coarser particles lodges among the vegetation near the streamward border of the third level. Thus dune ridges of coarser particles are formed paralleling the margin of the third level area, while the lighter, finer material is deposited more or less evenly over the remainder of the area.

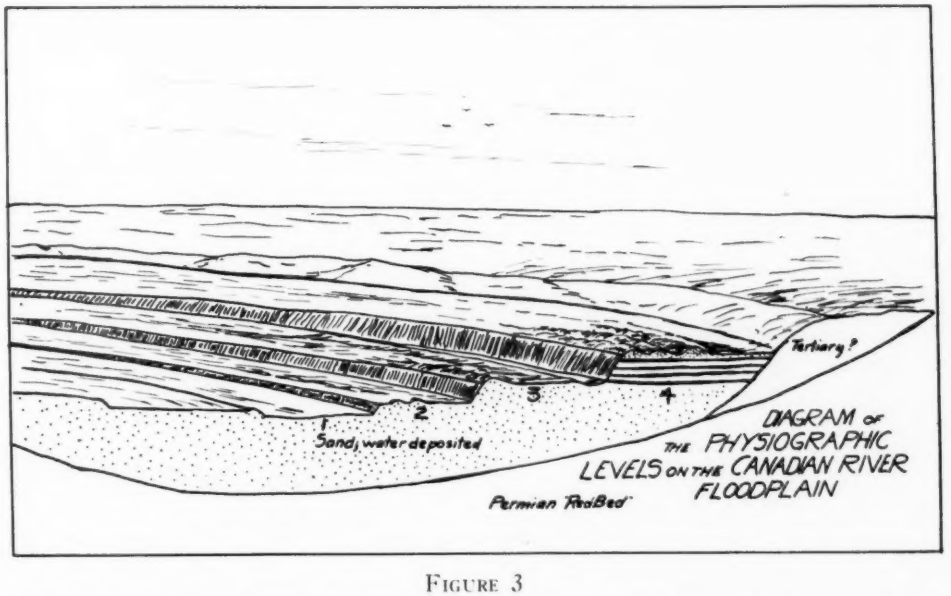

FIGURE 3

* Dr. V. E. Monnett, Director of the School of Geology, and J. W. Stovall, Assistant Professor of Geology, University of Oklahoma, believe that the stratified portions of the fourth level are probably of recent age.

THE FOURTH LEVEL.—This level is probably a true river terrace in the physiographic sense (at least certain portions of it are), and is considerably more complex in structure than the three lower levels. Portions of it are at most late Pleistocene age in the writer's opinion* but other portions are much younger geologically. Places where the river has cut during the past century and which have since been raised by aeolian deposition to the level of the older portions of the terrace, are indicated by the presence of subclimax vegetation, either "river-bottom" (*Andropogon furcatus*) prairie, or cottonwood parkland. The older portions thought to be of Pleistocene age

show alternating dark and light soil layers. The entire terrace is covered by a layer of recent aeolium.

A very characteristic feature of portions of the terrace which are of recent origin is the presence of ridge dunes covered either with parkland or prairie. These dunes parallel the river on the northeast side in a manner altogether similar to ridge dunes of the third level. They are, the writer holds, stabilized dunes which had their origin along the steamward margin of the third level, when the area was at this height.

CHANGES IN THE FLOODPLAIN EFFECTED BY CIVILIZATION

Before the advent of the white man conditions were much different on the floodplain. Marcy (1850) found great herds of bison and many deer on the uplands immediately bordering the portion of the floodplain studied. Washington Irving, 1832, camped a mile or two below the third group of stations and remarked the dense forest on the floodplain. Settlers* entering the country from 1880 to 1890 have described the floodplain as they first saw it; heavily forested on the fourth, and portions of the third level with massive bur oak, elm, black walnut, hackberry, ash, and pecan trees and wild grape and moonseed vines a decimetre or more in diameter hanging from them.

At the present time the timber has disappeared for the most part, only a few isolated relicts remain, and these are by no means in a natural state. The former woodland has been either cleared away for agricultural purposes, or washed away by the river during flood periods. Evans (1923) observed that torrential rains on the upper portions of the river basin caused these floods. This is doubtless true, but such floods were probably less frequent under primeval conditions. Destruction of the original ground cover on the uplands by heavy grazing and plowing up of the prairie sod, causing an increased run-off, increases the severity of such floods.

Since 1906 the river has increased the width of the bed and that of the second and third levels at the expense of the fourth, from less than half a mile, to more than two miles in some places, and during the flood of 1906 completely changed its course in the area studied for a length of more than three miles, cutting a new channel through the fourth level some two miles east of its original bed. Much of the territory between the old and new channels was reduced to first and second levels, and denuded. This area is now (1935) approaching the fourth level height, and is covered with cottonwood parkland.

The third level, according to all information the writer has been able to obtain, was comparatively narrow, but in some places is now more than half a mile wide. Its age varies considerably, but the portion studied has been built up from the second level since 1918 and is covered by various facies of a *Salix-Populus-Andropogon-Panicum Associes*. The second level is somewhat wider than formerly, and the first level is probably about the width it was before the country was settled.

* H. M. Hefley, Sr., Norman, Oklahoma, and Mr. Columbus Adkins, Norman, Oklahoma; personal communications.

THE PROBLEMS

Two problems closely interrelated are considered: (1) the description and evaluation of the various communities in the floodplain sere; and (2) the seasonal fluctuation in insect population of these communities. The causal agencies of distribution and fluctuation are also considered.

METHODS

Various methods were employed in gathering the data on which this paper is based. The historical portion was obtained by interrogating persons who came into the country before it was opened to settlement and who saw the Indian Territory as it existed prior to civilization.

The data concerned with succession were collected by the writer during the past two decades (1914-1934) under all sorts of conditions ranging from fishing trips "to the river" as a small boy to intensive cruisings on foot over the entire area during later years (1924-1934, and especially 1932-1934).

The data on the seasonal fluctuation of insect populations were taken in two ways. In the communities on the first and second levels of the floodplain the vegetation is too sparse and the invertebrate forms are either too wary or present in insufficient numbers to make quantitative collecting by sweeping a practicable or valid method. Quadrating is also impractical, since most animals move about too rapidly. The only other course was to observe the animals over and over and from the data obtained arrive at the relative abundance of the various forms.

In other communities where the vegetational components were well developed the sweet-net method was used to obtain quantitative collections and the relative abundance of the insect forms was ascertained in this fashion. These collections were made with a sweep-net with a handle one meter long and with an opening 40 cm. in diameter. In some cases 25 sweeps were made, but in most cases 50 sweeps constituted a unit collection. All data are tabulated in terms of 50 sweeps.

The graphic representations of the behavior of the populations and their component influent and sub-influent species (Figs. 25-33) were made by plotting one-half of the cube root of the actual number of animals taken against the time the collections were made.

Certain species were selected for discussion because of their presence in particular communities for the entire year, or because at certain seasons they gave a discernible aspect or physiognomy to the habitat with which they were associated. These were considered either as influents or subinfluents.

NOTE—On May 31, 1937, the Canadian River suffered a rise, the largest since 1906. This rise flooded all of the first, second, and third levels, and reduced the communities studied on these levels during 1933-34 to first and second level height, and to an initial status. The river did not flood the fourth level, but in many places under-cut it, so that areas more than a mile square in some places were washed away. This note is added as the paper goes to press. It is the author's hope that this will further emphasize the changing character of the Canadian River floodplain, especially since the upper portions of its watershed have been either plowed up, or overgrazed. (June 11, 1937. H. M. H.)

THE FLOODPLAIN SERE: SUCCESSION, AND SEASONAL DISTRIBUTION OF INSECTS

(Figure 1)

Initial communities in the Canadian river floodplain sere occur on the first three levels, and some of these are almost identical as far as their components are concerned. Their position with reference to physiographic features, however, and the factors concerned with their initiation make it impossible to consider them except as initial stages.

INITIAL COMMUNITIES OF THE FIRST LEVEL

Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes

(Station 1, Fig. 4)

This is the only initial community present on the stream bed. After the river has subsided after a slight rise, filaments of blue-green algae are seen near the surface of the sand within a week's time. Beetles (*Heterocerus pallidus* and *Bembidion laevigatum*) begin to burrow in the wet sand within a day or two after it has emerged from the water, and fly larvae *(Paralimna appendiculata)* are present from spring until early fall. Tiger beetles (*Cicindela hirticollis* and *C. cuprascens* mainly) are present during the summer months especially when the second level is quite dry. The beetles collect along the edge of the water on the wet bar to avoid the high temperatures of the dry sand, and also to obtain food.

The community is not transitory, since algae and beetles can be found on mild days even in mid-winter. It does not have a direct connection with the succeeding community except that as higher plant forms come in, the beetles and fly larvae drop out. Both forms are confined to bare, saturated sand and mud and do not appear in notable numbers elsewhere.

FIG. 4. First level initial community. *Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes* (Station 1).

Heterocerus pallidus

This little beetle was present in the community from its initiation to extinction. It first appeared a few days after the low bar emerged from the water. Its numbers varied with the seasons, very few being found during November, December, January, and February. On February 2, 1934, twenty were found on a square meter of sand, all adults. On May 1, 1934, seventy-one,

about half larvae, were found in a similar situation. It feeds on algae and humus detritus lodged in the sand, and inhabits wet sand and mud. It disappeared when blown sand was deposited over the wet bar and was completely absent after a layer of sand five cm. deep had been deposited between May 1, and June 17.

Bembidion laevigatum

Bembidions were present with the heterocerans in almost equal numbers. Both Bembidion and Heterocerus were often found occupying the same burrow, and were of equal importance in the community and ecologically similar.

Paralimna appendiculata

This fly was found from April 14 to October 26 as adults, from May 1 to August 13 as larvae, and from June 2 to November 25 as pupae. It passes the winter as hibernating adult, larva and pupa, since oviposition was observed as late as October 26, and adults were taken on December 12 in other communities. Like the beetles with which they were associated, both adults and larvae rapidly disappeared from the community after it was buried under a thin layer of blown sand.

Cicindela hirticollis
Cicindela cuprascens

These tiger beetles were members of the community from the middle of April until the third week in September. Both species fed on heterocerans, bembidions, and fly larvae, and were observed digging the victims out of their burrows. When temperatures were high, the tiger beetles were especially abundant, attracted by the cooler, moister sand, as well as by food. Swarms numbering into hundreds of individuals were observed in July and August, 1934, when the temperature of the sand on the adjacent second level ranged up to 67°C. (August 13). They completely disappeared by October 10.

Carex-Salix-Populus Associes

(Station 2, Fig. 6)

This community is from the standpoint of its dominants, initial, but is not strictly so, since an associes has preceded it. It appears in the early spring after the river has receded to a low level after spring freshets. *Carex* and *Salix* seedlings appear during the prevernal, and *Populus* seedlings appear in the vernal period. *Tamarix* may or may not be present, but in 1933 and 1934 was fairly abundant both as seedlings and as sprouts from roots and branches washed from farther up the river. This community plays a very important role in the establishment of the communities on the second level (see Fig. 1).

Bembidion laevigatum
Heterocerus pallidus

These beetles are the last remnants of the fauna from the preceding community. They disappeared by June 1, but were present in very small numbers during the spring.

Cicindela punctulata

The spotted tiger beetle inhabits situations where small open places alternate with vegetation. The beetle hunts in open areas, but when alarmed, hides beneath vegetation. It occurred in this community from June 2 until the middle of September No oviposition was observed but numbers of burrows were found among willow and cottonwood seedlings.

FIG. 6. First level community. *Carex-Salix-Populus Associes* (Station 2).

Cicindela cuprascens
Cicindela hirtocollis

These tiger beetles were seen in small numbers from July 1 until the last week in August. After rains fell from August 21 to 24 the beetles disappeared, migrating into adjacent communities on the second level.

INITIAL COMMUNITIES OF THE SECOND LEVEL

Xanthium-Carex-Salix-Populus Associes

(Station 3, Fig. 7)

This community is characteristic of level sand. It is initiated in late spring by the appearance of cocklebur seedlings; later sedges and willows appear, and finally cottonwoods. Cockleburs are decidedly the most prominent during the first year, since single plants may attain a spread of more than a meter by the end of the growing season. Associated with them are aphids and ladybeetles, and tiger beetles are present during the aestival and serotinal periods.

Cockleburs are important dune formers; drifts from a few centimeters

to more than a meter high may be formed around a group of these plants during a single summer. The roots tend to hold the drift in place during the winter, and new seedlings appear the following spring on top of the drift.

Cottonwood and willow seedlings attain a height varying from one to two decimeters to over a meter during the first growing season and develop sufficiently to dominate the community by mid-summer of their second year. Tamarix may or may not be associated with the cottonwoods and willows, but when present usually does not modify the associes to any marked extent unless it is present from the beginning in greater quantity than the endemic vegetation.

After the community is two or more years old its facies is changed by the appearance of *Andropogon furcatus, Pancicum virgatum,* and *Sorghastrum nutans.* Such grasses do not appear until the level has been raised a meter or more above the bed of the river.

FIG. 7. Second level initial community. *Xanthium-Carex-Salix-Populus Associes* (Station 3.)

Mutillidae

Velvet ants were observed from July 15 until the middle of September. Females digging burrows were seen from July 15 until September 1. Males were present flying back and forth above the ground during the same period.

Apion pennsylvanicum

This little weevil was first discovered on June 2 when the cockleburs were first beginning to bloom. It was present in some numbers until September 19, and had disappeared by October 10.

Cicindela hirticollis
Cicindela cuprascens

These two species of tiger beetles were present either as larvae or adults during the entire year. The larvae dig almost vertical burrows which varied from five to 35 centimeters in depth. They were unevenly distributed, vary-

ing from none to 10 or 12 per square meter. They did not occur in areas where the sand was actively forming drifts, but occupied slightly moist, hard, well packed sand. Adults were first observed on April 14 in small numbers and by July 7 had reached a maximum. During the extremely hot weather of July and August they decreased in numbers and migrated to the adjacent first level communities already discussed. On August 13, *C. cuprascens* larvae were seen quitting their burrows and moving to moister places where the heat was less excessive. After rains fell from August 21 to 24, the adults were again numerous in the community. They disappeared by September 19.

Haltica bimarginata

This species of gregarious chrysomelids occurred locally during late August and September as roving flocks on young willows. They did not reproduce in the community, but migrated from adjacent dune areas on the third level during the serotinal period. They moved in close flocks or swarms and congregated on a few shrubby willows in such numbers that the writer caught nearly two liters of them with half a dozen sweeps of a net. After defoliation was practically complete they moved en masse to a new location. They migrated to higher third level communities by the third week in October.

Tamarix Consocies

(Station 4, Fig. 8)

Before proceeding further it is necessary to give a short account of the origin of *Tamarix gallica*, and the reasons for its presence in the floodplain biota, and to describe its behavior along other streams.

The plant is a native of Asia and was from all accounts introduced into the southern and southwestern portions of the United States by early Spanish settlers three or four hundred years ago. At the present time it is well established in the southwestern portions of Texas, and in Colorado and New Mexico. It is extensively used as a shade tree in portions of the Southwest where conditions are semi-desert in nature, and the soil strongly alkaline.

Tamarix blooms profusely and produces immense numbers of seeds. These find their way to favorable places especially along rivers where colonization results. Along the Pecos River between Ward, Reeves, Crane, and Pecos counties, Texas, Tamarix has formed closed associations, the trees ranging up to three decimeters in diameter and fifteen meters high. Forest reproduction is going on in these consociations to the exclusion of the endemic vegetation.*

Tamarix is grown locally for ornamental purposes in the upland section of the country surrounding the portion of the floodplain studied but the writer does not believe that the Tamarix on the floodplain is the result of

* Writer's observation, summer of 1931.

spreading from these shrubs. There is no Tamarix on the floodplain 50 miles down the river from the portion studied; on the other hand, it is present on the floodplain above the portion investigated and also on the upper parts of the floodplains of the Cimarron and North Canadian rivers in western Oklahoma.

Seedlings appear on the bare portions of the second level especially in early spring, but also after heavy showers at any time during the season of growth. Growth is rapid; in one consocies initiated July 1, and averaging 51 per square meter the plants grew 20 cm. in height by August 15, 1934. Other consocies initiated in the spring (April, 1934) attained a height of 12 decimeters and *bloomed* in late summer (August) of the same year. The ability of the plant to form dense growths of seedlings which rapidly develop into thickets effectively eliminates other mid-seral plants for competition is too great for many of the latter to endure.

FIG. 8. Second level initial community. *Tamarix Consocies* (Station 4).

Cicindela punctulata

This tiger beetle was the only insect present in sufficient numbers to influence the aspect in any way. It occurred from April 14 to October 19 as adults. Larval instars were not present.

Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes

(Station 5, Fig. 5)

This initial alga-animal community is similar in major respects to the initial community on the river bed. It differs from this in being on a higher

level and on a sub-stratum of mud. There is a proportionately smaller number of flies and fly larvae present in the "mud-flat" community also.

The duration of the community is transitory. Seedling willows and cottonwoods appear during the late spring. These may be intermixed with Carex and Tamarix. The advent of these plants in the community causes the initial components to drop out; sand drifts over the mud and lodges around the bases of the plants, and the community is obliterated by the time the lodging sand reaches the height of the surrounding level sand.

FIG. 5. Initial second level community. *Cyanophyceae-Heterocerus-Bembidion-Paralimna (Mud Flat) Associes* (Station 5).

Heterocerus pallidus
Bembidion laevigatum

These burrowing beetles were present from a few days after the river receded from the second level after small floods until the community was obliterated by sand drifting over it. Obliteration is usually complete within three months after initiation.

Paralimna appendiculata

These flies were associated with the beetles as larvae, but appeared about two weeks after the recession of the water during spring, summer, or fall. They were not present during the winter.

Cicindela hirticollis
Cicindela cuprascens

Both of these tiger beetles frequented the mud flat in large numbers from April until October, congregating there to escape the high ground temperatures of adjacent communities and to prey upon the insects present in the mud.

Scirpus-Typha-Chara Associes

(Station 6, Fig. 9)

This is not strictly a second level associes. It is in many respects quite similar to the *Sagittaria-Typha-Chara Associes* which occurs on the third level. Its animal components, its dominants and its physiographic position are sufficiently distinct to consider it as a separate community.

In some places, especially near or downstream from localities where tributaries of the river cut across the third level on their way to the bed of the

river, shallow, sluggish channels are present on the second level. The most noticeable thing about them during the hiemal and prevernal periods is the stonewort, *Chara*, growing profusely in the bottom of the channels. By the end of the prevernal period, the *Chara* is practically gone, and *Scirpus* becomes abundant along the edges of the channels. *Typha* appears by the middle of the vernal period and in some instances blooms by the end of the aestival period.

FIG. 9. Initial second level community. *Scirpus-Typha-Chara Associes* (Station 6).

Culex sp.
Chironomus sp.

Mosquito larvae were present in the water from February 2 until June 1. The adults were especially numerous during March, April, and May. They were not present during July and August but a few were encountered in September and early October. Midges were present as adults from February 4 until the water disappeared July 7. The larvae were present during the winter and spring, persisting until the water dried up on July 7.

Empoasca radiata

This leafhopper was present in considerable numbers from May 1 until October 1 in patches and clumps of *Scirpus*. A few were also taken among cat-tails. No nymphs were found, and the insect apparently migrated in from adjoining communities.

INITIAL COMMUNITIES ON THE THIRD LEVEL

Sagittaria-Typha-Scirpus Associes

(Station 7, Fig. 10)

This community is the direct successor of the *Scirpus-Typha-Chara* community described above. As sluggish channels become older the level of their beds is raised along with the level of the surrounding area not only by the deposition of wind-borne material, but also by the deposition of fluvium

FIG. 10. Initial third level community, *Sagittaria-Typha-Scirpus Associes* (Station 7).

by tributary water. In addition, humus deposition is rapid because of the luxuriant growth of hydrophytes. *Sagittaria* appears as a band or zone in the water's edge, while *Scirpus* and *Typha* are present in the stream from previous associes. Smartweed, *Polygonum hydropiperoides*, follows the *Sagittaria* and is in turn replaced by willow and cottonwood seedlings.

Napaea breviceps

These flies were present from February 4 until the middle of October. They were present in large numbers, and were found along the muddy bank close to the water among *Typha* and *Sagittaria*.

Paralimna appendiculata

Paralimnids were present in the vegetation from April 14 until October 9 as adults. They apparently congregated there to escape strong winds in the more open portions of the floodplain.

Thyridopteryx ephemeraeformis

Bagworms were found on cat-tails from June 7 until November 10, although *Tamarix* and willows are their preferred food. They will apparently eat almost any vegetation with which they come in contact. Bags containing eggs were found during the winter on dried cat-tails.

MID-SERAL COMMUNITIES OF THE SECOND LEVEL

Tamarix Consocies

(Station 8, Fig. 11)

This community occupies a unique position on the second level since it is (from the standpoint of its plant components) only a more advanced stage

FIG. 11. Mid-seral second level community. *Tamarix Consocies* (Station 8).

of the *Tamarix Consocies* initiated here. By the time the community has reached its second year of growth, however, it gains an influent and a subinfluent, *Chlorotettix viridis* and *Ceratomegilla fuscilabris*, respectively, the presence of which separates and delimits it from other communities on the floodplain.

Chlorotettix viridis

This green leafhopper occurred only during August as a casual migrant from older associes on the third level. Reproduction occurred, but few nymphs were found.

Ceratomegilla fuscilabris

This beetle was present during the month of August also. Its presence was directly correlated with the presence of immature leafhoppers. It disappeared as soon as the leafhoppers matured and its food supply was exhausted.

Salix-Populus-Andropogon-Panicum Associes

(Station 9, Fig. 12)

This community occurs on level sand. It may have its origin from the *Carex-Salix-Populus Associes* on the first level by the cottonwood and willow persisting during the building up of the area to the height of the second level, by the disappearance of the *Carex*, and the subsequent appearance of *Andropogon furcatus, Panicum virgatum*, and *Sorghastrum nutans*.

It may originate from the initial *Xanthium-Carex-Salix-Populus Associes* on the second level by the disappearance of the cockleburs and sedges, and the appearance of the grasses. It may also arise from willow and cottonwood seedlings starting on mud-flat areas and withstanding the physiographic evolution of the areas into sand flats.

FIG. 12. Mid-seral second level community. *Salix-Populus-Andropogon-Panicum Associes* (Station 9).

The community has various facies. Some *Carex* may persist locally from first level communities; cockleburs may also be present in restricted areas persisting from previous second level *Xanthium-Carex-Salix-Populus Associes*. *Tamarix* may be present in some places and when in sufficiently dense stands may eliminate the endemic vegetation and throw the sere toward a *Tamarix Consocies*.

If there is a dominance of cottonwood and willow locally, a proportionately larger amount of sand lodges around these and transitory dunes are formed on the second level. On the whole, young trees and grasses are in about the same relative numbers and are rather evenly spaced, so the level is raised in general to third level height evenly.

Cicindela hirticollis
Cicindela cuprascens

These tiger beetles were present from March 14 until October 5 as adults and during the entire year as larvae. Adults reached a maximum in numbers in early July, decreased to a very few by the latter part of August, and increased again in September. Larvae were active during spring, summer and fall, and on mild days during the winter.

Ceratomegilla fuscilabris

Ladybeetles were found only during the aestival and serotinal periods. They were first noticed on June 2, and were gone by September 30. No larval instars were found. The insects apparently migrate as adults from adjoining third level communities to feed on aphids which occur on willow and cottonwood trees during these periods.

Aphidae

Aphids were found from June 2 until September 30 on cottonwoods and willows. Their distribution was discontinuous; some trees had a plentiful supply (from 5 to 50 per leaf) while others had none.

Empoasca radiata

This leafhopper was found associated with clumps of *Andropogon furcatus Sorghastrum nutans*, and *Panicum virgatum* from July 7 until September 30. It was occasionally found on willows also. It was never abundant, but the largest numbers were observed on August 13, indicating that one brood probably matured in the associes. No nymphs were taken, however.

Salix-Populus Dune Associes

(Station 10, Fig. 13)

This community may have its origin from the initial *Carex-Salix-Populus Associes* on the river bed in a manner similar to the *Salix-Populus-Andropogon-Panicum Associes* on the second level except that during aeolian deposition a relatively greater amount of sand lodges around the cottonwood and willow components than over the remainder of the area, resulting in dunes or drifts. It may also arise from the second level initial *Xanthium-Carex-Salix-Populus Associes*, or from the mid-seral *Salix-Populus-Andropogon-Panicum Associes*.

The community has several facies. Cockleburs and sedges may persist. The former aids materially in dune building, but the latter is eliminated as soon as the dunes assume a height of a meter or so. The hawk moth, *Pachysphinx modesta occidentalis*, is associated with the cottonwoods on these young dunes, and the checkerboard beetle, *Plectrodera scalator*, is a conspicuous influent during the aestival period. The gregarious chrysomelid, *Haltica*

bimarginata migrates from higher levels and is present from mid-summer until early fall.

Tamarix is sometimes present on young dunes especially when the plants were two or more years old before dune formation began. It does not seem to be able to withstand dune formation as seedlings or as plants less than two years old.

Haltica bimarginata

Halticids preferred dune to level communities in the floodplain. In this associes, however, they appeared only in the late aestival and serotinal periods (August 13 to September 19). They did not reproduce but came in as roving bands or flocks of adults numbering into the thousands of individuals and remained until they moved into third level dune communities for purposes of hibernation.

FIG. 13. Mid-seral second level community. *Salix-Populus (Dune) Associes* (Station 10).

Pachysphinx modesta occidentalis

These large hawk moths were present throughout the year either as adults, pupae, or larvae. Their food plant is the cottonwood and they prefer low trees growing on shifting dunes. The imagoes appeared late in May and deposited eggs which hatched from four days to a week later. The larvae matured slowly pupating the second week in July. The second brood of moths emerged in mid-August and the resulting larvae pupated from the middle of September to the first week in October. These remained in the sand over winter and emerged late the following spring. Pupation took place in the sand beneath the cottonwood trees on which the larvae were situated. They burrow into the sand to a depth of about 20 cm. and there construct an ovoid cell of silk and sand in which pupation occurs. The insects are

important since three or four larvae will almost entirely strip a tree two meters high and two or three meters across.

Plectrodera scalator

These large striking longhorns were present throughout the year. Adult beetles appeared about the first of July in large numbers and remained until the latter part of August. Ten or a dozen were often found on the trunk and larger branches of a single small cottonwood. The eggs are deposited at or slightly below the surface of the soil in cracks in the bark. The larvae are borers and inhabit both the roots and the trunk of the trees. The duration of the larval instars is probably two years, since there were two distinct sizes of larvae found in May, one ready for pupation, and the other about half grown.

Cicindela formosa

C. formosa typically inhabits wooded dunes. It did not occur in large numbers in this associes since trees were not large enough and the area was both too young and too small. It occurs most frequently on dense cottonwood dune parkland on third and fourth levels. Adults were present from July 7 until September 19.

Mutillidae

Velvet Ants were present during the period between July 7 and September 19. Females dug burrows in the loose sand and in one instance (August 13) a pair were seen in copula.

MID-SERAL COMMUNITIES OF THE THIRD LEVEL

Salix-Populus-Andropogon-Panicum Associes

(Station 11, Fig. 25)

This community is the direct successor of the *Salix-Populous-Andropogon-Panicum Associes* described on the second level. It differs from the latter in being more mature, cottonwood and willow seedlings are absent, grasses are more abundant, and seasonal stratal socies are present.

All other mid-seral communities on the third level may take their origin from this associes by the segregation and differential development of its codominants. At the height of its development the community resembles a meadow with grasses and willows one to two meters high. The cottonwoods vary from one to six or seven meters in height. *Tamarix* may occur locally and when abundant forms consocies by eliminating the endemic vegetational components. In some places also, Indian grass *(Sorghastrum nutans)* is present, and may almost completely replace *Panicum*. During late winter and early spring a very apparent ground covering of moss forms a seasonal stratum in which snails and ground beetles are characteristic animals. This stratum is absent during the remainder of the yearly cycle.

Sweet clover, *Melilotus alba*, appears for the first time in this associes. It forms extensive facies, dominates local portions of the community during the aestival and serotinal periods and forms a low herb stratum during the winter and spring.

Crematogaster lacvisucula clara

Ants were active in the vegetation except during the winter and early spring. They were first taken in collections on June 6 and reached a maximum July 7. A single individual was taken November 16. At no time did ants occupy a position higher than that of sub-influents in this community.

Melanoplus sp.

Grasshopper nymphs were present in collections from June 17 until July 3. In the case of grasshoppers, the numbers taken in sweep-net collections did not give a good index of their relative abundance since they are easily flushed and usually escaped the net. Adults of *Melanoplus bivittatus* and *M. differentialis* were present from July 2 until November 25 in large numbers, yet only one individual of each species was taken in sweepings. *Schistocerca americana* was present and was taken only once. Grasshoppers collectively occupy the position of an influent group in the associes, but quantitative collections do not demonstrate this assumption.

Empoasca radiata

This leafhopper was collected only during the autumnal and early hiemal periods and was present for purposes of hibernation. Examination of tussocks of *Andropogon furcatus* and *Sorghastrum nutans* on February 4 revealed *E. radiata* hibernating in the crowns.

Cicadella hieroglyphica

This cicadellid likewise hibernated in the crowns of bluestem and Indian grass during the colder portions of the winter. One specimen was taken on September 30, and 34 on November 25, which was unusually warm.

Phalacrus politus

Phalacrids appeared as summer and fall members of the community, appearing May 1 and disappearing October 19. They were associated with willows, especially where the willows and bluestem were of about equal height and distribution. They were not numerous; 14 was the largest number taken in a single collection (August 13).

Stictocephala lutea

These membracids were strictly serotinal and autumnal components. They first appeared September 30, reached a maximum in numbers November 9 and were not taken in collections after November 25. Such behavior would indicate that they probably hibernate here, but no such individuals were found. The species did hibernate in a contiguous community, however.

Tamarix-Chlorotettix Consocies

(Station 12, Figs. 14, 26)

Tamarix third level communities may have their origin from several sources. The most direct origin may be traced to the initial *Tamarix Consocies* on the second level which has persisted during the physiographic growth of the area to third level height.

The communities may also originate from facies of the *Salix-Populus-Andropogon-Panicum Associes* and the *Salix-Populus-Dune Associes* of the second level by eliminating the other components through competition. It may likewise have its origin from facies of the *Salix-Populus-Andropogon-Panicum Associes* on the third level.

The *Tamarix-Chlorotettix Consocies* on the third level represents the highest seral stage the plant has reached at the present time (1935). Fifteen years ago there were no communities in the sere which even had facies of *Tamarix* and the writer knew of only one clump some three meters across in the entire portion of the floodplain studied. Since this time, however, the plant has undergone ecesis with remarkable facility, witnessed by extensive consocies now more than three meters high on the third level, which was intermediate between the present second and third levels a decade and a half ago. These consocies take the form of dense thickets; the soil beneath is completely shaded during the vernal, aestival, and serotinal periods, and mulched by a layer of *Tamarix* leaves one to 10 cm. thick during the autumnal and hiemal periods. Shading and mulching of the floor effectively prevent the establishment of invaders.

FIG. 14. Mid-seral third level community. *Tamarix-Chlorotettix Consocies* (Station 12).

To what length the *Tamarix Consocies* will go and whether it will eventually form an edaphic climax consociation is problematical. Similar communities on the Pecos River Floodplain in Texas have assumed climax consociational rank by effectively preventing ecesis of natural vegetation. It is probably that the plant will in time come to occupy a similar position in the floodplain sere of the Canadian River, although at present it has only reached a mid-seral stage.

The ability of the *Tamarix* to survive the combined onslaught of the leaf-hop-

pers and dry weather was striking. After rains fell from August 21 to 24, the then bare *Tamarix* was in full leaf 10 days later and some plants even *bloomed* by September 15!

Chlorotettix viridis

This leafhopper was unique in its behavior. It was a good example of an endemic insect quitting its native food plants and attacking an exotic form. It was present throughout the year, hibernating during the late winter in the duff and exerting great control during the remainder of the year. *Chlorotettix viridis* must be classed as an influent of the first order with reference to the degree of control it exerts. It appeared as adults late in May, and by the middle of June nymphs and adults were present in great numbers, 1051 being taken in a 50 sweep sample June 18. It reached a maximum the third week in July when 4,258 adults were taken in a 50 sweep sample. After this time it decreased in numbers rapidly because of a number of interacting factors.

The aestival period was unusually hot and dry. The leafhopper population was excessive. Consequently the *Tamarix* shed its leaves the second week in August with disastrous results to the insect population. On July 19 there were decidedly more cicadellids present than the community could support. The nymphs were already beginning to perish; thousands were on the ground, dead.

Ceratomegilla fuscilabris

Ladybeetles preyed extensively on leafhopper nymphs both as larvae and adults. Beetles reached a maximum about a month before the leafhoppers, were present before their appearance in the spring, and disappeared by October 4. *C. fuscilabris* did not hibernate in the community, but migrated to the contiguous fourth level during the early autumnal period and remained there during the winter.

It did not exert much influence on leafhopper numbers since it was present in insufficient numbers to do much in the way of decreasing them. It did add a decided aspect to the community at the seasons during which it was present and is therefore considered as a sub-influent.

Thyridopteryx ephemeraeformis

The bag worm is another native species which has become accustomed to an exotic plant, and has forsaken its native food plants to some degree. Young larvae with bags less than 2 mm. in length appeared by mid April. As the season progressed they decreased in numbers, and by June 18 averaged 17 per *Tamarix* plant. They were in the third larval instar at this time. When the defoliation due to leafhoppers and dry weather began in late July the bag worms either migrated to adjoining sedges, cottonwoods, and willows and changed their food plant completely, or remained and perished. Many attempted to seek food, but did not survive migration and

starvation. The ground beneath the *Tamarix* was heavily mulched August 1 with cases containing the dried up remains of the luckless larvae.

Oecanthus quadripunctatus

The four spotted tree cricket was present in small numbers during the aestival (May 21-June 18), serotinal (June 19-August 25), and autumnal (August 26-November 6) periods. It was observed feeding on the pollen of *Tamarix* during the spring and early summer, and on honey dew secreted by leafhopper nymphs at later seasons. No immature tree crickets were taken.

Lygus pratensis

The occurrence of lygids in the consocies was directly correlated with the time of flowering of the *Tamarix* in the early and mid-aestival period (May 21-June 18). These bugs appeared on the flowers in fairly large numbers and rapidly disappeared after the plants ceased blooming.

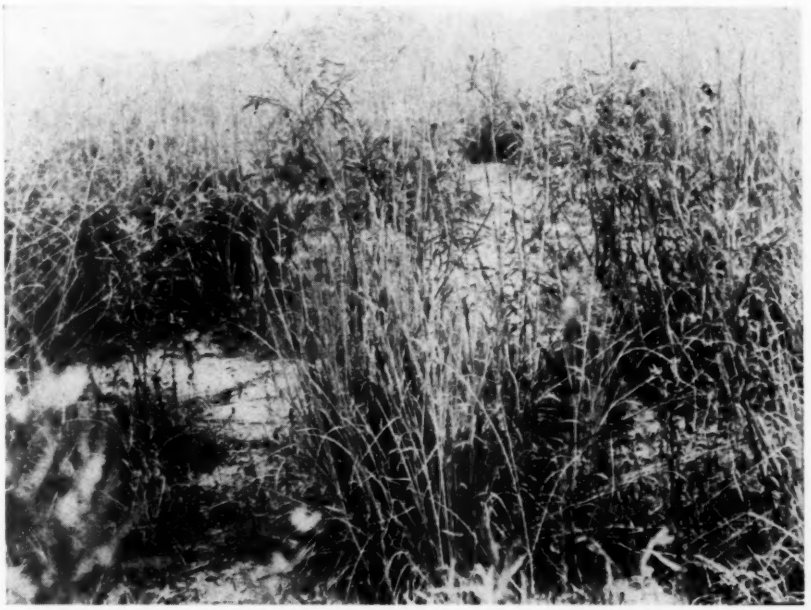

FIG. 17. Mid-seral third level community. *Andropogon-Panicum Associes* (Station 13).

Andropogon-Panicum Associes

(Station 13, Fig. 17)

This associes is developed from the *Salix-Populus Andropogon-Panicum Associes* by an almost complete dropping out of the cottonwoods and willows and the development of the grasses to a position of dominance. It occupies older portions of the bench which are usually at a slightly higher level. This community is stratified as is the *Salix-Populus-Andropogon-Panicum Associes* and for the most part is similar in aspect. Willows when present are not at all numerous and form restricted facies, while cottonwoods are

absent. Sweet clover is locally present, but not as extensively as in the younger *Salix-Populus-Andropogon-Panicum Associes;* neither does it attain a position of local dominance here.

Acrididae

Grasshopper nymphs were abundant from May 1 until June 18, but were not seen during the remainder of the summer. They appeared again in early September and went into hibernation about October 10. A very small number were seen on warm days during November, December, and February.

Schistocerca americana

This large locust was present from July 19 until March 11 as adults and from March until August as nymphs. It was the most characteristic insect of the associes. The adults were active during the milder portions of the winter and it was a rather surprising experience to flush one of these large locusts in mid-winter. It was not abundant during any season, but for that matter, the insect population of the community is extremely sparse.

Cicadella gothica

This cicadellid inhabited portions of the community with stunted willows from June 18 until September 10. It was not taken elsewhere and is apparently restricted to the facies in which its food plant, the willow, is present.

Salix-Populus-Polygonum-Paralimna-Napaea Associes

(Station 14, Figs. 18, 27)

This community is in most respects an older and more developed stage of a sluggish channel associes. Willows are decidedly dominant, and the *Sagittaria* has dropped out. Water covers the ground only during the spring, and for short periods in other seasons following heavy rains. Napaeid flies are present from spring until late fall, and paralimnids are numerous. The latter does not breed in this community, however, but the adults apparently congregate here to escape the wind and drifting sand so often present on their breeding grounds.

Napaea breviceps

This fly was present from spring until late fall (Feb. 4-Nov. 4) in considerable numbers. It reached a maximum June 2, when 610 were taken in a single collection of 50 sweeps. It was not taken during the winter. It was especially abundant in low herbs close to the edge of the water, and congregated during the hotter portions of the summer on the muddy banks of the channel.

Paralimna appendiculata

Paralimnids were taken from April 14 until October 30; also on December 7 and February 4. They were present in great numbers on June 2,

when 200 were taken in a single collection. The flies apparently seek shelter from wind and sandstorms, and hibernate as adults during the winter.

Trypetis albiceps

Trypetids were present from October 5, 1933, until April 14, 1934. They were absent until September 19, 1934, when they again appeared. They apparently migrated from adjacent habitats for hibernation and moved out immediately after emergence in the spring. These flies were common during the early fall on the flowers of *Polygonum*.

FIG. 18. Mid-seral third level community. *Salix-Populus-Polygonum-Paralimna-Napaea Associes* (Station 14).

Lygus pratensis

This insect is quite definitely a resident of the community during the aestival, serotinal, autumnal and hiemal periods. It migrates into the associes as soon as *Polygonum* begins to bloom and remains as long as these flowers are present. No hibernating forms were found during the winter although one was taken on December 7. It did not reappear the following spring. It was again observed the following fall when the smartweed began to bloom.

Stictocephala lutea

This membracid hibernated here. It was first observed moving in on September 30. It increased in numbers to a peak on November 9, then disappeared from collections by December 7. Examination of the willow thicket floor on the edges of the channel in December and February revealed the insect numb and almost motionless at the bases of the willows. It was taken

in collections again on June 17, but was not present during the remainder of the aestival, and serotinal periods.

Empoasca radiata

E. radiata was a member of the community from early summer to the beginning of the autumnal period. It appeared suddenly on June 17, at which time 50 were taken in a single 50-sweep collection. Thereafter it was present in small numbers until November 16. It was not found in hibernation.

Populus-Salix Associes

(Station 15, Figs. 15, 28)

Communities of this type may have either of two origins; from the *Salix-Populus-Polygonum* community along secondary channels on the third level, or from the *Salix-Populus-Andropogon-Panicum* community on the third level. In the former case the *Polygonum* drops out caused by a filling up or a shifting of the secondary channel, and shading by trees. When formed from the cottonwood-willow grass community, the willows sink to a secondary and the cottonwoods rise to a primary position; the grasses either disappear entirely because of competition and shading, or are present in numbers too small to be considered as dominants. *Tamarix* is often present but is not able to assume even locally a position of dominance since cottonwoods out-rank it both in size and numbers. It persists in more open places for an indefinite period and is eventually shaded out. Sweet clover forms extensive facies especially when the community has been derived from the *Salix-Populus-Andropogon-Panicum Associes*. It forms a low herb stratum during the hiemal, prevernal and vernal periods and may locally attain a position of subdominance during the aestival and serotinal periods. Associated with it as elsewhere because of food preferences, are grasshoppers and cottontail rabbits.

FIG. 15. Mid-seral third level community. *Populus-Salix Associes* (Station 15).

Cicadella gothica

This leafhopper was a component of the community during the entire yearly cycle. It was never taken in exceedingly large numbers yet was so constant in its presence and so closely associated with the

willows that it should be considered one of the most characteristic animals of the community. It was taken in collections during early February and was also found at this time hibernating at the bases of willows and cottonwoods, and in the crowns of sweet clover. It was active by March 11 and appeared in collections in considerable numbers then. During April and May it almost disappeared, being represented in collections by only a few nymphs. Adults again appeared on June 18. These represented the first, or early aestival brood. A single nymph was taken July 19 but from this time until the collections were discontinued October 10, the species was absent. The previous fall when collections were begun the insect was quite abundant.

Chlorotettix viridis

This species was present in far greater numbers than *Cicadella gothica*. Its presence was due to some *Tamarix* being scattered among the native vegetation and its presence here with few exceptions parallels its behavior in the *Tamarix-Chlorotettix Consocies* already described.

Populus-Salix-Cicadella-Haltica Dune Associes

(Station 16, Figs. 2, 29)

This community is characteristic of dune ridges on the third level and is formed from *Populus-Salix Associes* on level areas when they are situated at or near the streamward margins of the bench. Cottonwoods are decidedly dominant and willows have sunk to a sub-dominant position. Cicadellids are present throughout the year, and the chrysomelid, *Haltica bimarginata* is abundant in the spring, early summer, and winter. *Tamarix* occurs locally and forms doubtful facies in restricted localities, but is not adapted to a dune habitat. The community is the forerunner of cottonwood parkland dune communities on the fourth level.

Haltica bimarginata

The behavior of these little blue beetles was very interesting. They occupied one of the most important as well as characteristic places in the insect fauna of the community. The adults hibernated in the loose sand around the bases of the cottonwood and willow trees and beneath a litter of fallen leaves and twigs. They went into hibernation between October 31 and November 7, and remained dormant until April 9. At this time the willows were just beginning to show traces of new growth half a centimeter or less in length, and the beetles were actively crawling up the twigs and literally fighting for a chance at the young leaves, forming balls of up to a hundred individuals around the new growth. Rabbits had peeled many of the smaller willows during the previous winter, and where sap was flowing from trees so wounded many of the beetles were congregated drinking sap and gnawing at the cambium.

Numbers of copulating pairs were seen on April 9. By the latter part of the month the beetles were practically gone. One was taken in a collection made April 29, while 467 were taken April 9. They were absent during May, straggling individuals were present June 27, and none were taken during July. They began to appear gradually during the first week in August and by September 9 were again numerous. They increased in numbers until the middle of September, after which there was a decrease in numbers taken, since hibernation began at this time.

These beetles are probably double brooded in this region. The adults oviposit soon after coming out of hibernation in restricted fácies of young willow communities on the third level of the floodplain. The writer has observed halticid larvae in such places, but never on the second level. The larvae, like the imagoes, are gregarious. Whether a group of larvae is the result of a single clutch of eggs, or whether several females lay their eggs together could not be determined. Likewise, it was impossible to determine whether a flock of adults had been together as larvae.

At any rate, when the adults emerge late in the summer, they band together in swarms and become seized with a sort of "wanderlust," invading communities on the second level, particularly the dune associes (see Station 10, *Salix-Populus Dune Associes*) where they wander about throughout the serotinal period, stopping where willows are present, forage is good, and the habitat is acceptable. Late in the serotinal or in the early autumnal period they again seek third level dune communities in preparation for hibernation.

Cicadella gothica

This large cicadellid was probably the most characteristic member of the insect population, being present in all except the aestival period. It appeared in considerable numbers September 8, and was taken in the largest numbers October 24. The insect did not undergo hibernation except during cold periods. It was very active among the willows on mild days during midwinter. It decreased in numbers taken from December 4 until March 9, then increased to a spring maximum April 29. It rapidly decreased after this date and was absent by the latter part of May. It appeared in greatest numbers in the fall when the adults collected to spend the winter.

Dorytomus squamosus

This weevil was present throughout the year either as larvae or as adults. Imagoes were associated with the willows from February 17 until May 30 and reached a maximum in numbers on April 9. A single individual was taken October 31. The immature instars are spent in the stems of young willows.

Andropogon-Schistocerca Dune Associes

(Station 17, Fig. 16)

This dune community is derived from the *Andropogon-Panicum Associes* on the third level when it is situated near the streamward border of the bench. It differs in topographic features and in the plant components, since *Andropogon scoparius* occurs sparingly on the dune crests, and *Panicum virgatum* has dropped out. Stunted willows form local facies but have reached their maximum height (two or three meters) and are on the way out. Where the grasses are sparse cockleburs form restricted facies, but are present only in the younger communities.

Schistocerca americana

This large locust was a member of the community during the entire year. It hibernated as adults during the winter, but a warm winter afternoon was sufficient to bring it into activity: The writer flushed several of these grasshoppers on Christmas Day (1933); old, tattered individuals but nevertheless quite lively. Females were observed ovipositing in small bare areas March 20, and the first nymphs were seen July 3. Adults became abundant in late August and early September.

Schistocerca obscura

This locust seemed to exhibit a preference for portions of the community where stunted willows were present. Like *S. americana* it was found during the winter months as adults. The nymphs were first seen July 3, feeding on willows. Adults appeared August 8, about three weeks earlier than *S. americana*.

FIG. 16. Mid-seral third level community. *Andropogon-Schistocerca (Dune) Associes* (Station 17).

Cicadella gothica

This leafhopper was present only during the aestival period. It was associated with willows and appeared both as nymphs and adults. It is interesting to observe that it was absent from the contiguous *Populus-Salix-Cicadella-Haltica Dune Associes* during this period. It is concluded, therefore, that the species migrated into this community during the early aestival period and reproduced here during the summer, but went back to the dune community at the beginning of the serotinal period.

SUB-CLIMAX COMMUNITIES OF THE FOURTH LEVEL

The sub-climax communities in the floodplain sere are confined to portions of the fourth level which have not been disturbed by the river for a century or more. They fall into two physiographic groups, level land and dunes, and into two ecologic categories, parkland and prairie.

Prairie Associes (on level areas)

(Station 18, Figs. 19, 30)

This prairie is developed from the *Andropogon-Panicum Associes* on the third level. At the present time it consists of *Andropogon furcatus-Andropogon scoparius* prairie, with some *Poa pratensis, Panicum virgatum* and *Sorghastrum nutans* in local, lower, moister places.

The presence of the little bluestem is due directly to grazing, in the opinion of the writer. Indeed, the entire community is being held in a more or less static condition by coaction (grazing). In 1885* the identical area

FIG. 19. Sub-climax fourth level community. *Prairie Associes* (Station 18).

studied had a complete cover of big bluestem "as high as the shoulders of a man on horseback," and abounded in deer. As late as 1926 there were indications of a former luxuriance of bluestem, with scattered clumps of persimmon and young cottonwoods throughout the area, indicating that it would ultimately be succeeded by parkland. Since that time the river bottom has been heavily overgrazed; *A furcatus* seldom blooms, and *A. scoparius* has appeared where it normally does not belong. Shrubbage has disappeared. Forest reproduction at the ecotone between prairie and parkland has ceased, and in many places ruderals have appeared in the overgrazed prairie communities.

* The writer's father, H. M. Hefley, Sr., first saw the area in 1885 and killed a large buck there. Because of the tall grass, hunting was done on horseback. There has been some doubt cast of late that bluestem could be this high in this part of Oklahoma. The accounts of hunting expeditions given the writer during his childhood and later by both his father and grandfather leave no doubt in his mind that "tall prairie bottom grass" actually existed. The prairies of bottom and upland alike have been so overgrazed and exploited for the past 50 years, however, that it is easily understood why the past two generations are doubtful of the former luxuriance of the prairie grass.

Solubea pugnax

S. pugnax was present throughout the year. It was conspicuous in collections from early August until the middle of December. During the winter it was found as adults deep in the crowns of *Andropogon scoparius*, hibernating. Nymphs appeared in collections from August 4 until October 24. The insect matured late in the autumnal period and began to hibernate within a week or so after the last nymphal ecdysis.

Thamnotettix kennicotti

This cicadellid was present during the entire year, hibernating in tussocks of grass during the winter and inhabiting clumps of bluestem during the remainder of the year. It reached a peak in numbers in early September, and went into hibernation a week later. It appeared in the spring on April 9, but was absent from collections until July 3 when examination of the grass tufts revealed a few adults and many nymphs at their bases. It was taken September 9.

FIG. 20. Subclimax fourth level community. *Cottonwood Parkland Associes* (Station 19).

Cottonwood Parkland Associes

(Station 19, Figs. 20, 31)

The *Cottonwood Parkland Associes* on the fourth level is developed from the *Populus-Salix Associes* on the third level. The willow has disappeared for the most part and single, isolated, mature trees in lower places are the only evidence of their former presence. The cottonwoods are from eight to 18 meters high and from 35-80 years old, according to ring counts. Most

of them are about 50 years of age. A decade ago the community was distinctly stratified; wild grape and moonseed vines were present, while dogwood (*Cornus alba*) and black haw (*Viburnum* sp.), formed a well defined shrub stratum. *Andropogon furcatus* was present in the more open portions of the community.

In its present condition (1935) young ash and elm trees, formerly present also, have disappeared. The black haw is entirely gone, and the dogwood persists as closely browsed stubby shrubs. Most of the bluestem has vanished and persists only in a few isolated patches. Sandburs (*Cenchrus* sp.) are abundant everywhere and other ruderals (*Ambrosia, Lactuca, Pyrropappus,* and *Jatropa*) are quite abundant. Forest reproduction and invasion into adjacent prairie has stopped because of intense pasturing. The cottonwoods are approaching maturity, and in the course of another quarter century the area will become badly overgrazed prairie if the present conditions continue. If left undisturbed it would ultimately give rise to *Edaphic Climax Elm-Oak Forest.*

Brachymyrmex sp.

This ant is the only insect which was present in sufficient numbers to be considered. The paucity of insect forms in the associes was due directly to the way the area has been pastured for the past decade. Over 60 head of cattle were grazed in the area (about 100 acres) for a year previous to the time the writer's studies were made and during the time they were in progress. Most of the cattle bedded beneath the cottonwoods during the winter and congregated there to fight flies during the summer also.

Such coaction is not favorable to insects normally occupying parkland, and the only survivor was the ant, *Brachymyrmex.* It became active April 29 and was most abundant June 27 when males and queens swarmed. After this date it was present in considerable numbers until October 17 when it went into hibernation.

Dune Prairie Associes

(Station 20, Fig. 21)

Dune prairie communities on the fourth level are derived from the *Andropogon-Schistocerca Dune Associes* on the third level. They differ in being more advanced, on a higher level, and in that *Andropogon furcatus* is usally absent and replaced by *A. scoparius.* Occasionally, *Bouteloua curtipendula* appears on the crests where the ground cover is sparse due to overgrazing.

These dune prairie communities are in much the same condition as the flat prairie communities in the river bottom; they were formerly heavily covered with grass, and clumps of sand plum and persimmon were scattered throughout. Now the shrubbage is gone, the grasses are depleted, blowouts are numerous, and the communities are being held static by coaction.

Sphex speciosus

These big, ill-tempered wasps were present from the middle of June until the first week in September. Grassland dunes appeared to be a favored place for them to dig their nests. Females were especially noticed during July digging, or dragging cicadas through the grass to their burrows. As adults, they do not feed on cicadas but stock their burrows with them as food for the developing larvae. On hot summer afternoons they were observed buzzing around cattle congregated in the shade of nearby cottonwoods catching *Stomoxys calcitrans* (stable "biting" flies) after the manner of "bald-headed" hornets *(Vespa maculata)*. The sphecids devoured the flies while on the wing. They were also observed to drink sap flowing from wounds in cottonwoods and willow trees.

FIG. 21. Subclimax fourth level community. *Dune Prairie Associes* (Station 20).

Mecidia longula

Facies of *Sporobolus* were the preferred habitats of this stink bug, since it was present through the year in them. Adults appeared in late August and hibernated among the roots of the grass during the winter. They became active late in April, and nymphs appeared from June 15 until the middle of August.

Cottonwood Parkland Dune Associes

(Station 21, Figs. 22, 32)

This associes arises from the *Populus-Salix-Cicadella-Haltica Associes* on the third level. The trees are scattered and mature. Some are already dead, and others partly so. There is no shrub story except in local areas where there are small clumps of plum. The most apparent grass is *Andropogon scoparius* and the chief forb is *Stillingia sylvatica*. Formerly the community was in many respects similar to the level parkland, and was stratified, with a rising young tree story composed of elm and hackberry and a

shrub story of dogwood and black haw. A decade of heavy pasturing has eliminated these; the grass is now sparse, and blow-outs are numerous.

Empoasca radiata

Leafhoppers of this species were present throughout the year, reaching a maximum in numbers October 3. They gradually diminished in activity during the autumnal period and went into hibernation beneath grass roots the last week in November. They came out of hibernation about April 9 and reached a spring peak in numbers on this date. Adults were not found during the latter part of May, but nymphs were present by the middle of June and adults by early July.

FIG. 22. Subclimax fourth level community. *Cottonwood Parkland Dune Associes* (Station 21).

Draeculacephala mollipes

This draeculacephalid was a fall and winter resident of the community. It appeared first on October 17, and reached a peak of abundance on October 24, and began to move into hibernation by the last week of the month, congregating beneath dead stalks of *Stillingia* and in the crowns of *Andropogon scoparius*. It was taken in collections until December 4. It came out of hibernation in April; one individual appeared in the collection taken April 29. It was absent during other seasons.

CLIMAX COMMUNITY OF THE FOURTH LEVEL

Edaphic Elm-Oak Forest Association

(Station 22, Figs. 23, 33)

This association, formerly extensive on the fourth and portions of the third level exists now only as relicts. The community studied is relatively "young" in terms of the forest climax which existed before the advent of civilization, since gigantic cottonwoods are present, some fallen, some dead and standing, and others still living. These cottonwoods are the last remnants of the sub-climax cottonwood parkland associes. Many elms are mature, a few are dead, but none have yet fallen. The oaks, *(Q. macrocarpa)* are not yet mature since few are over 50 cm. in diameter and they are lower in stature than the elms. There is a large amount of hackberry present also. This tree forms local faciations. The ash is mature, and many are partly dead.

The association is well stratified; buck-brush (*Symphorocarpos* sp.) forms a low shrub stratum, and young elms, oaks, and hackberries form the young tree layer. The herb stratum is composed chiefly of violets and burr marigolds.

The canopy is closed except near the forest edge and where cottonwoods have fallen and broken down the neighboring trees. A few pecan trees are present and some box-elder grows in the forest edge. Vines are well developed but are not as large as those described by early settlers in the floodplain forest under primitive conditions. Grapevines reach to the tops of some elm trees, but moonseed and *Smilax* are confined to the younger, smaller trees.

FIG. 23. Climax fourth level community, *Edaphic Climax Elm-Oak Forest Association* (Station 22).

Epitrix brevis

This little beetle was present in sweepings taken from April until October. It was also found in the duff during the winter but in very small numbers. Considerable numbers were taken October 19, but it disappeared rather suddenly, going into hibernation before November 1. They appeared in large numbers during the aestival and serotinal periods.

Apion pennsylvanicum

Huge numbers of this little black weevil were swept from herbage on April 21. They persisted in diminishing numbers until June 18, then disappeared. It was neither seen nor taken at other seasons. Its behavior indicates hibernation in the community but examination of the duff failed to disclose it. The small size and color of the insect makes it quite difficult to perceive in litter, however.

Stictocephala lutea

This membracid was a fall, winter and early spring component of the association. It began to move for hibernation in early September and was apparently concentrated in the herb stratum by October 10. It was in hibernation by December 12 and in the duff around the bases of green briars (*Smilax* sp. one of its food plants) and young hackberry trees. It became active the first week in February and from this time was absent from collections until the following September 8.

Strongylocornis stygicus

This bug appeared May 21, and was present in great numbers on June 18. It was associated with the flowers of the coral berry *(Symphoricarpos)* and was not present after the shrub ceased blooming.

Culex sp.
Chironomus sp.

Mosquitoes and midges were present as adults during the vernal, aestival, serotinal, and autumnal periods. They retired beneath the leaves of low vegetation during the day, but were observed in the early evening in swarms near the forest edge. Many individuals were taken in sweep-net collections.

DISCUSSION

Cowles (1899) investigated the plant communities of the dunes of Lake Michigan in relation to meteorological factors, describing plant communities in their developmental relations. Two years later (1901) he concluded that physiographic factors are the most striking causes of vegetational changes. His conclusions apply equally to the Canadian River floodplain, since the combined action of wind and water are the factors which determine the trend ecesis takes. Ecesis in turn determines the sequence of communities up to the sub-climax stages of the sere.

The floodplains of Illinois rivers have been studied to some extent by Turner (1933) and Gleason (1910) in relation to the grassland areas present in them. Turner observed that the "customary" floodplain forest is confined to a belt or zone a few hundred yards to half a mile wide paralleling the river channel, and that the "landward" side merges into a grass association, at first on the hydric side of mesophytism, but giving way in turn as the elevation of the floodplain increases to a mesic grass formation. Although he mentions zonation, he holds that clear-cut seral stages are not discernible. His ideas do not apply to the Canadian River floodplain, nor for that matter to any river floodplain the writer has observed. Even on streams with practically no floodplain there is a distinct series of seral stages in the form of narrow bands or zones. The wider the floodplain and older the river the more complex the initial and mid-seral stages in the sere become.

Baskina and Friedman (1928) investigated the animal components of two association on the Kama River floodplain. These communities were at different topographic levels, and had a different plant composition also, one being grassland, and the other an herb community. A greater heterogeneity of invertebrate forms was found in the population of the older community (presumably grassland; although the authors do not say) than in the younger one. No seral study was made.

Simur's description (1933) of the "forest associations" on the Obla River near Lebochovice, Czechoslovakia, reveals willows, *Phragmites* and *Scirpus* in marshy places (doubtless mid-seral communities) and beech forest on the "high banks." He makes no reference to succession and zonation, but describes both.

Barclay (Harriet George, 1924) studied the portion of the Mississippi River floodplain between Minneapolis and Saint Paul, Minnesota, from the standpoint of plant succession. She found that cottonwoods and willows are the dominant species of the initial communities on low terraces, and that cottonwoods and river maples are the dominants of higher terrace young subclimax communities. The mature floodplain forest dominants are American elm, and green ash. This forest according to Barclay constitutes a higher subclimax stage, and there is no climax forest present. Her analysis of the river succession shows cottonwoods and willows in the same stages in the Mississippi River sere which they occupy in the Canadian River sere.

The ecologic investigations of Tharp (in Sellards, Tharp, and Hill, 1923) on the floodplain of the Red River valley between Texas and Oklahoma in connection with a boundary suit between the two states* merits especial mention, since the two rivers are essentially alike in aspect, physiography, surface geology, and behavior. The ages of the different levels in the floodplain were considered, and the oldest (4th) determined as probably dating from the Pleistocene. The third, second and first levels were found to be of variable

* The full record appears in the records of the Supreme Court of the United States, No. 23 Original, Oct., 1920, and No. 20 Original, Oct., 1921, Vols. i to ix, 5-513 pp.

ages, and were referred to as reclaimed land and sand flats. The summary of ecologic investigations is quoted in part, verbatim.

The climax stage of plant development for the region in which the Big Bend area is located is designated by Clements as the short grass modification of the mixed prairie association.

The treeless portions of the Big Bend valley have virtually attained the climax association, as is indicated by comparing an analysis of the vegetation of such with that of the bluffs on both sides of the river.

While the length of time required for the vegetation of a given area to pass from initiation to climax cannot be definitely stated in years, there is much evidence to support the view that it must take several hundred years: e.g.

1. Upon a tract on the Oklahoma side of the Grandfield Bridge, which in its oldest portion must have exceeded 100 years, only 10 climax dominants have become established.
2. At the southwestern limit of the cottonwood savannah, estimated to be upwards of 150 years of age, only five of a total of 18 climax dominants noted for the valley in this area had appeared.
3. Using the conditions as they exist in the cottonwood savannah as a basis for judgement, it seems entirely conservative to estimate 150 years as the minimum time required for the cottonwood stage to pass from initiation to extinction.
4. There is no evidence of greater correlation between the age of the oldest trees in the valley and the minimum and maximum age of soils which support them than there is between the same comparative ages of the trees and the soils along upland stream courses.

The writer found (as did Tharp) that it takes a century or more for the cottonwood parkland (Tharp calls it savannah) to arise, mature and disappear.

Parkland is subclimax, and arises on first and second levels but matures on fourth level areas, since the levels on which cottonwood seedlings become established are built up physiographically during their development. Assuming as Tharp does that it takes 150 years for the community to mature and disappear, then it takes about the same length of time for first or second level areas to be built up to fourth level height.

It is known that certain cottonwood parkland associes on the Canadian River floodplain are 29 years old* (Township 9, range 4 west: McClain Co., Oklahoma: Southeast corner of township). They were denuded first and second level communities 29 years ago but are now of a height intermediate between the third and fourth levels. Ring counts made on stumps of trees cut in 1933 revealed from 20 to 26 rings.

SUCCESSION IN THE CANADIAN RIVER FLOODPLAIN

The floodplain communities are *edaphic communities* in a sere which leads to an edaphic forest association while the uplands surrounding the floodplain in the central portion of Okahoma are covered with mixed prairie, the *climatic climax* of the region.

* The flood of 1906 cut the present channel of the river across a former bend and reduced the area now covered with cottonwood parkland to first and second levels. Authority: the writer's father, H. M. Hefley, Sr.

Because of physiographic and edaphic features the climax of the floodplain sere is forest rather than grassland. The edaphic climax forest located on the fourth and portions of the third level of the floodplain is an extension or tongue of forest extending westward into the prairie because the more mesic conditions of the floodplain enable it to do so.

Since late Pleistocene times (when the oldest portions of the fourth level were probably formed) the river has meandered back and forth, cutting down portions of its floodplain to first and second levels and leaving these portions for the most part devoid of macroscopic life. On the bare areas thus formed initial communities have developed. Many are destroyed repeatedly by the river soon after they are formed, but some communities are not disturbed. These associes undergo biotic and physiographic succession simultaneously, reaching a subclimax prairie or cottonwood parkland stage after a century or longer, and approaching the fourth level height after about three decades.

New initial communities are formed every year by the river's meanders. These in turn are succeeded by mid-seral stages which vary from one to twenty-five years in duration. Younger communities are nearer the river channel and are at lower levels.

In some cases the identical trees which become established as seedlings on the first *(Populus)* or second *(Populus, Tamarix)* levels may persist through the intervening stages and take part in the formation of subclimax communities on the fourth level. As far as these trees are concerned the process is one of development rather than of succession. However, when other plants and especially insects are considered, successional relationships become apparent.

Insects which were not present previously come into each successive community. These may persist in older communities but it will be noticed (Fig. 4) that their distribution is not continuous and that no influent or sub-influent species is present in more than three serally related associes. Therefore, although certain animals are common to several associes the successive appearance of forms new to the sere leaves no doubt as to the distinctness of the component communities and their seral nature.

Blake (1925) concluded that animals of subalpine communities show a definite succession from bare or lichen covered rock communities, to climax coniferous forest. Animals present in the younger stages of the sere were absent in the subclimax and climax stages. Stratal migration was also reported.

His general statements regarding the demonstration of succession by animals are in agreement with the results of the present investigations.

CHANGES DUE TO CIVILIZATION

Van Deventer, 1934, investigated the influence of man on biotic communities, and his findings are applicable to the modified conditions now extant on the Canadian River floodplain. He found that with the introduction of

civilization into a primitive area, a definite biota of plant and animal forms, exotics, parasites and weeds, which survive best in a man-modified environment comes in also. Civilization causes the disappearance of many components of the original biota, even to the climax vegetation and many of the animals dependent on it. He concluded that after an area has been under the influence of civilization for a century or longer, the modified biotic community tends to strike something of a new balance, quite different from the original climax.

The floodplain sere has been extensively changed by two plants brought in by man. These are *Tamarix gallica* and *Melilotus alba*. The former has already formed prominent consocies and facies and the latter has formed extensive facies. The balance a community strikes after having been invaded by an exotic as hypothesised by Van Deventer has not yet been reached on the floodplain because too short a time has elapsed. These exotics are not yet present in climax and subclimax communities as might be the case had a new balance been attained.

Illichevsky (1933) found that in certain rivers of Russia, the inundated portions of the floodplains have a very different flora than the higher, non-inundated portions. His conclusions that rivers are active agents in plant distribution are obvious. No better example can be found than that of the spread of *Tamarix gallica* along the Canadian River from plants set by early Spanish settlers in the territory near its headwaters. Illichevsky also mentions zones and bands of vegetation which parallel eastern European and Siberian rivers. He makes no specific mention of succession, but the writer suspects that the zones are of associes rank despite the fact that he apparently considered them closed communities.

According to Grossheim and Prilipko (1929) on the Kura River in the Karabakh Steppe *Tamarix pallasii* and *T. hohenacherii* occupy positions somewhat similar to those now occupied by *Tamarix gallica* on the Canadian River floodplain.

Macrozones parallel the rivers, as well as the foothills along the rim of the steppe. Along the rivers first is situated a "microcyperetum," or an "agglomeration" of cyperaceous plants. Next is a zone of "gallery forest" composed of *Salix australitor* and *Populus hybrida*. The third zone is composed of *Tamarix pallasii* and *T. hohenacherii* and in turn grades into the steppe community. While the species of willow and poplar are not the same, they have the same growth form and are present in similar seral stages on the Canadian River floodplain.

Tamarix appears to be well on the way to effecting a permanent change in the Canadian River sere by changing the climax from the present elm-oak forest to a pure stand of Tamarix.

The plant gained a foothold on the Pecos River floodplain in southwestern Texas somewhat earlier than on the Canadian River floodplain and during

the past thirty-five years has completely replaced the endemic vegetation in many localities. Some time will have to elapse before similar conditions obtain on the Canadian River floodplain, but the writer believes they will ultimately do so.

SEASONAL FLUCTUATION OF THE INSECT POPULATION*

The behavior of the insects in the *Elm-Oak edaphic climax association* in the floodplain sere (Fig. 33) agrees in general with Weese's findings (1924)

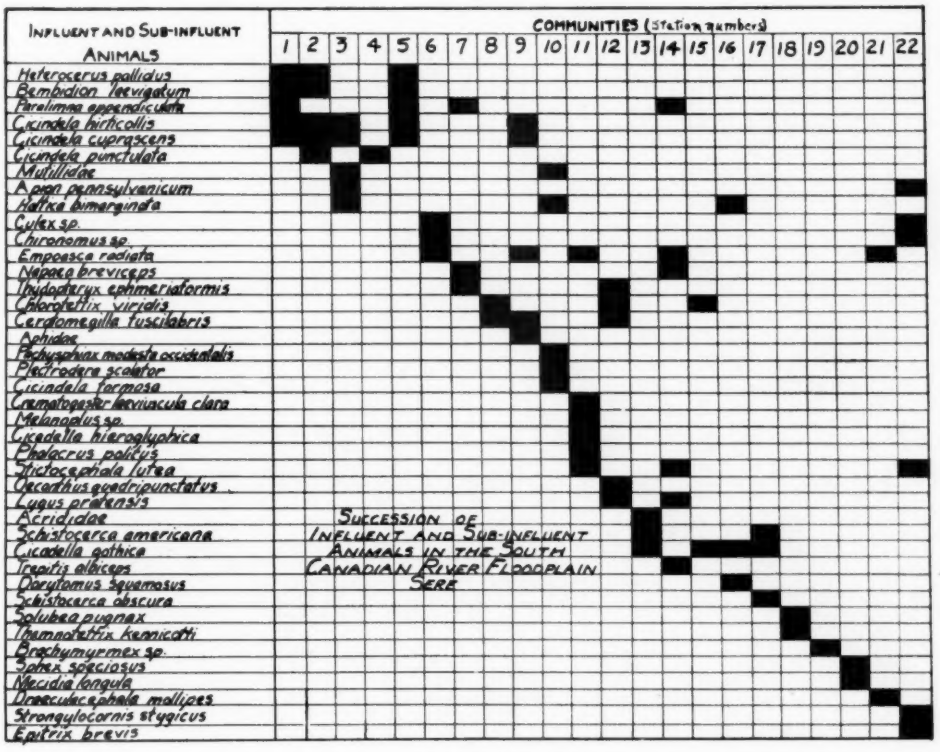

FIGURE 24

COMMUNITIES

First Level

Station Numbers

1 Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes
2 Carex-Salix-Populus Associes

Second Level

3 Xanthium-Carex-Salix-Populus Associes
4 Tamarix Consocies (initial)
5 Cyanophyceae-Heterocerus-Bembidion-Paralimna Associes
6 Scirpus-Typha-Chara Associes
7 Sagittaria-Typha-Scirpus Associes
8 Tamarix Consocies (mid-seral)
9 Salix-Populus-Andropogon-Panicum Associes
10 Salix-Populus Dune Associes

Third Level

11 Salix-Populus-Andropogon-Panicum Associes
12 Tamarix-Chlorotettix Consocies
13 Andropogon-Panicum Associes
14 Salix-Populus-Polygonum-Paralimna-Napaea Associes
15 Populus-Salix-Associes (level areas)
16 Populus-Salix-Cicadella-Haltica Dune Associes
17 Andropogon-Schictocerca Dune Associes

Fourth Level

18 Prairie Sub-climax Associes (level areas)
19 Cottonwood Parkland Sub-climas Associes
20 Dune Prairie Sub-climax Associes
21 Cottonwood Parkland Dune Sub-climax Associes
22 Elm-Oak Association. Edaphic Climax Forest

* Detailed lists of species are on deposit in the library of the University of Oklahoma.

with regard to the seasonal fluctuation in numbers of insects in an Illinois Elm-Maple forest. Maxima in numbers occurred in May and October both in the river forest and the Illinois forest. The beetle *Epitrix brevis* Schwarz was one of the most characteristic insects in fall and spring in both associations.

The associes in which quantitative collections were made differed as to the behavior of their insect populations. Subclimax communities varied considerably in the time of their population maxima. The *Cottonwood Dune Parkland* total insect population (Fig. 32) reached maxima in June and October; the June maximum was due to the insects migrating into the community and multiplying there, the October high was caused by the maturing of summer broods and migration from continguous communities.

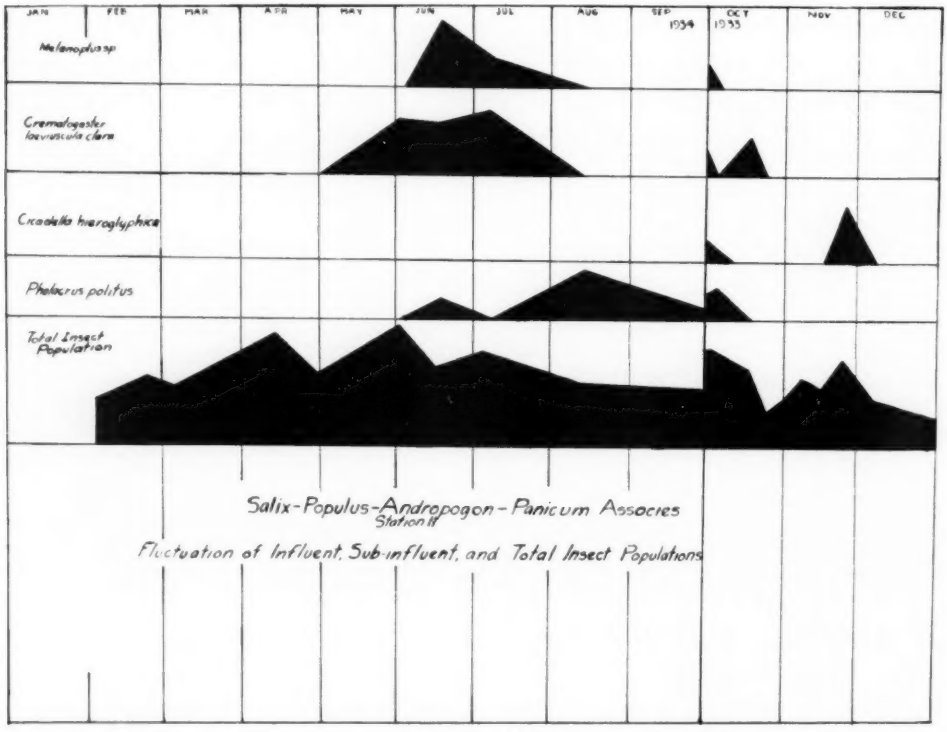

FIGURE 25

Level Parkland insects (Fig. 31) showed a decided maximum in July and slighter peaks in numbers in early May and late October. The latter maxima indicate a beginning of a behavior on the part of the population similar to that of the climax association but the peak in July indicated that the community still has decided mid-seral affinities.

The insect population of the *Edaphic Subclimax Prairie Associes* (Fig. 30) increased from a minimum in March to a slight peak in late June, another in August and an autumnal peak in October. The June and August maxima were caused by the appearance of mature forms, and the fall rise

was due to a combination of this and some migration. Migration was not thought to be of much importance here since some forms migrated from, rather than into the associes during the autumnal period.

Mid-seral communities varied considerably in the time of the insect maxima. The youngest of the communities investigated quantitatively (*Salix-Populus-Andropogon-Panicum* Associes on the third level; Fig. 25) had a slight prevernal maximum (February), a decided vernal (April), an early aestival (June), an autumnal (October), and an early hiemal (November) maximum.

The *Salix-Populus-Polygonum-Napaea-Paralimna* Associes (Fig. 27) reached a population maximum in early July and showed only traces of autumnal and hiemal maxima. These two associes are contiguous on the third level and the aestival peak in the latter was due to migration of paralimnid flies from the former and from initial communities, and the appearance of the adults of *Napaea breviceps*.

The unusual number of peaks in the population of the *Salix-Populus-Andropogon-Panicum* Associes (Fig. 25) was caused by the action of several factors. The April maximum was caused by insects coming out of hibernation or appearing as imagines from wintering pupae. The June and July peaks represented the summer broods of the various insect components while the October increase was the result of insects moving into hibernation. The November peak was in all probability not a true maximum but the result of an unusually warm day, since the community was sheltered from north winds by fourth level forest, and the collection of November 5 was taken at 2:30 P.M. when the air temperature was 17.5° C. The preceding collection was taken when the air temperature was 7.1° C. This probably explains the "peak" in numbers in the November 5 collection.

The population of the *Populus-Salix* Associes (Fig. 28) showed maxima in May and September indicating that the community had already begun to show affinities in its behavior with the cottonwood parkland subclimax associes and the climax forest association.

The *Tamarix* Consocies (Fig. 26) did not show marked affinities with other communities. It had by far the greatest total number of insects of any community in the sere. The population reached a maximum in July and then declined. The most of the population was composed of the leafhopper, *Chlorotettix viridis*. The early summer maximum and the absence of other crests, however, indicated the mid-seral nature of this community.

The *Populus-Salix-Cicadella-Haltica* Dune Associes (Fig. 29) on the third level showed three definite crests in the seasonal fluctuation of its population, one in April caused by the emergence of cicadellids and halticids from hibernation, another late in May caused by the increase of cicadellids, while the autumnal peak in late October was produced by both cicadellids and halticids moving in for hibernation. The May and October maxima

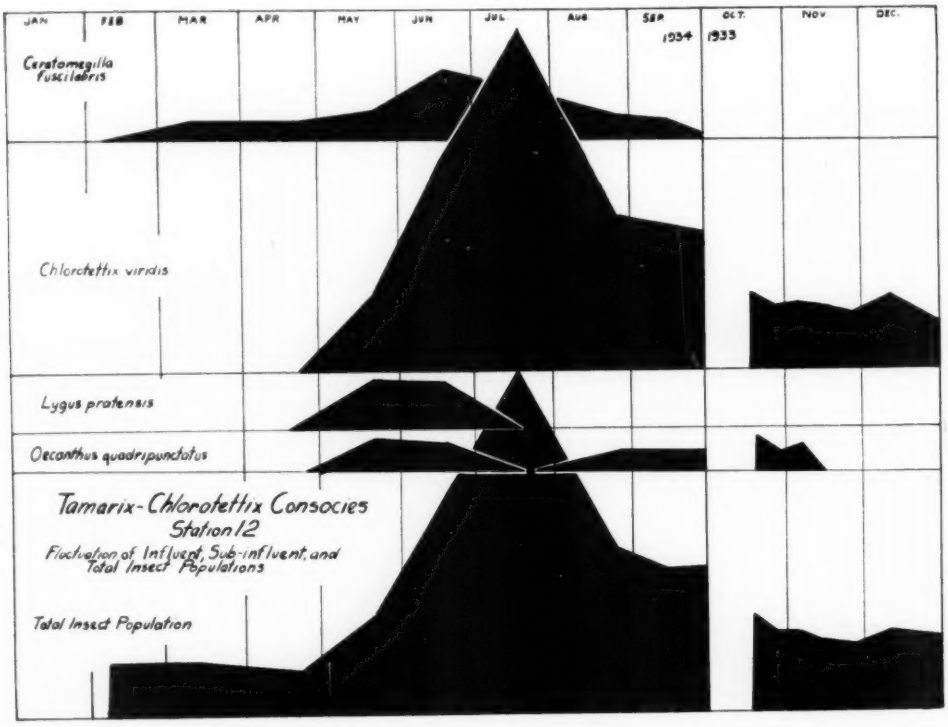

FIGURE 26

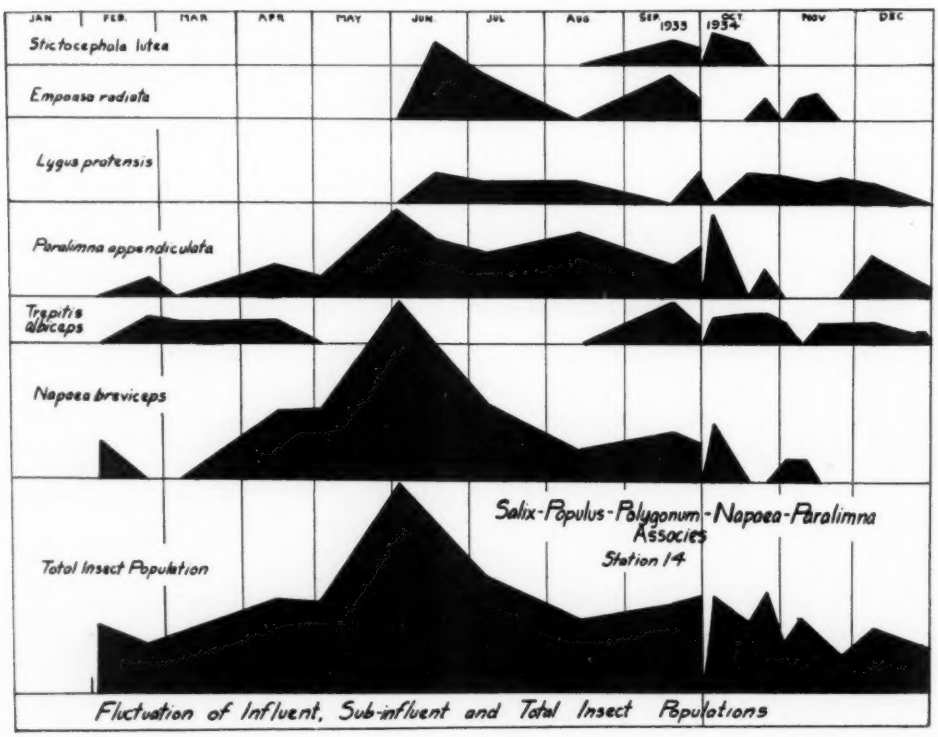

FIGURE 27

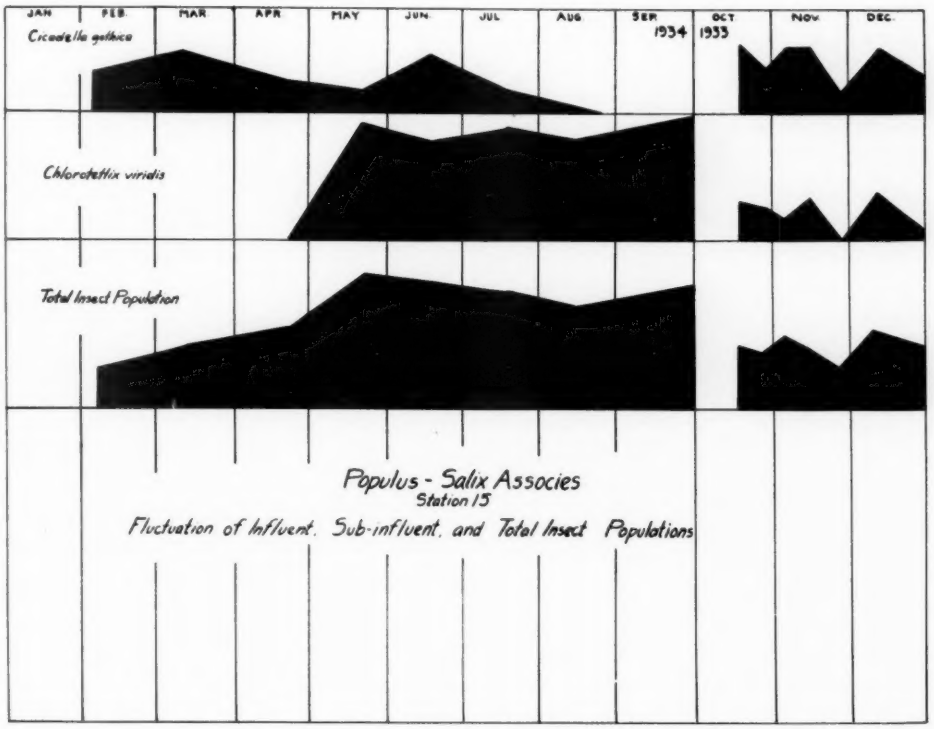

FIGURE 28

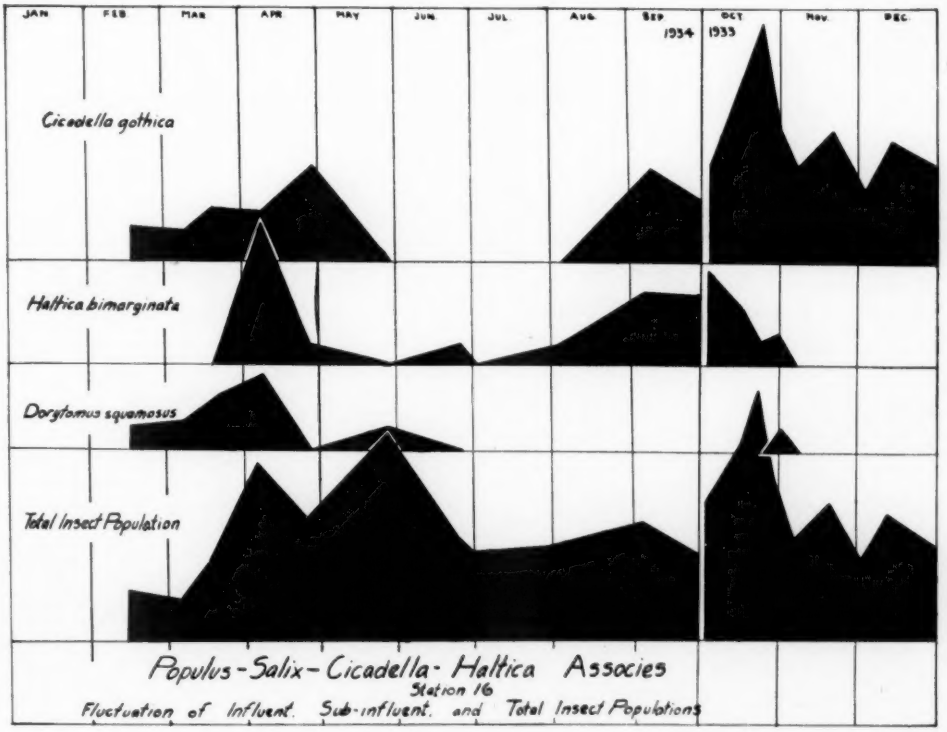

FIGURE 29

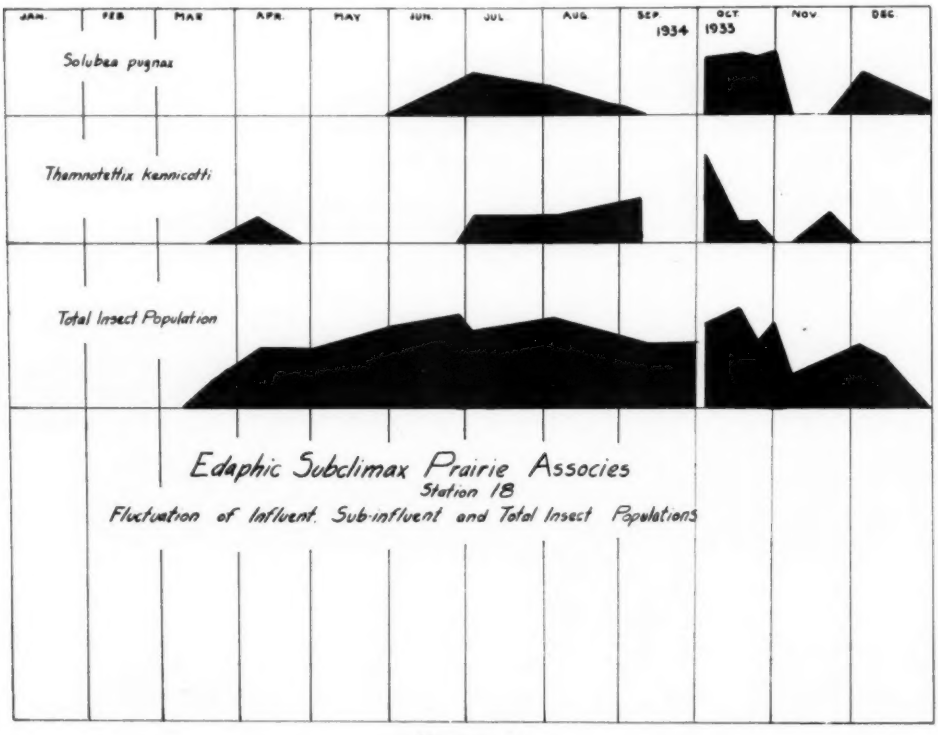

FIGURE 30

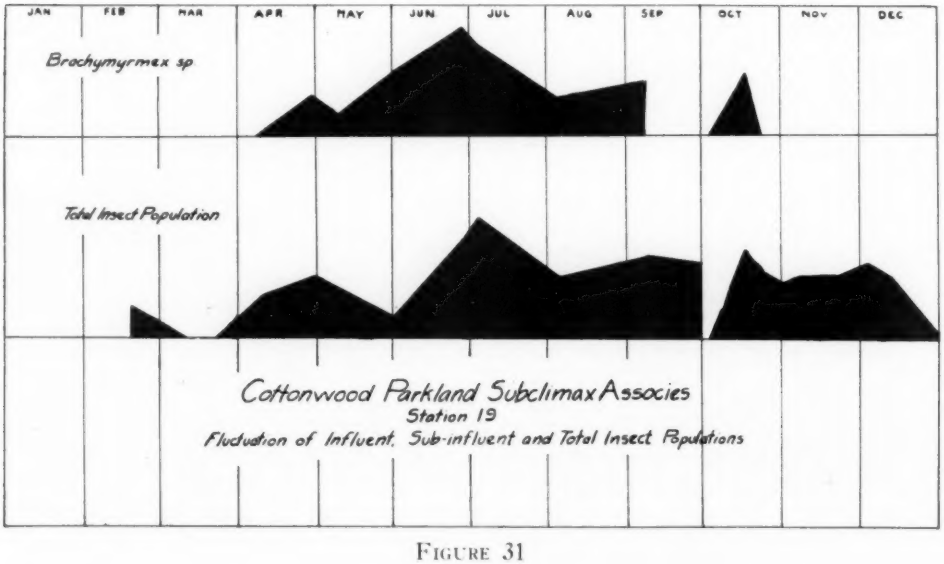

FIGURE 31

suggests that the associes is approaching a sub-climax condition but the early spring crest shows that the community is still mid-seral.

Among the earlier contributions dealing with land populations are the papers of Wolcott (1918), McAtee (1907), and Banks (1907). All of these investigators studied definite areas. Wolcott dealt casually with the suc-

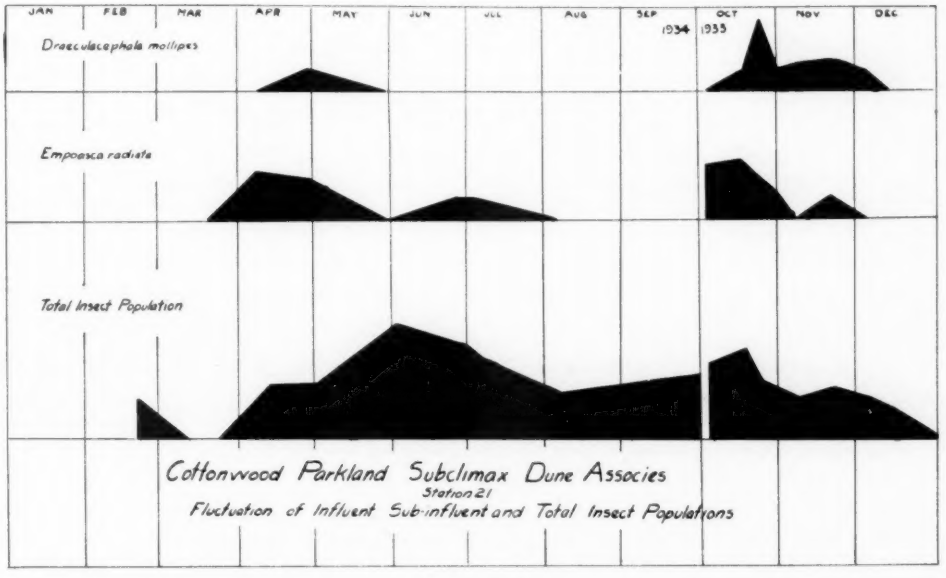

FIGURE 32

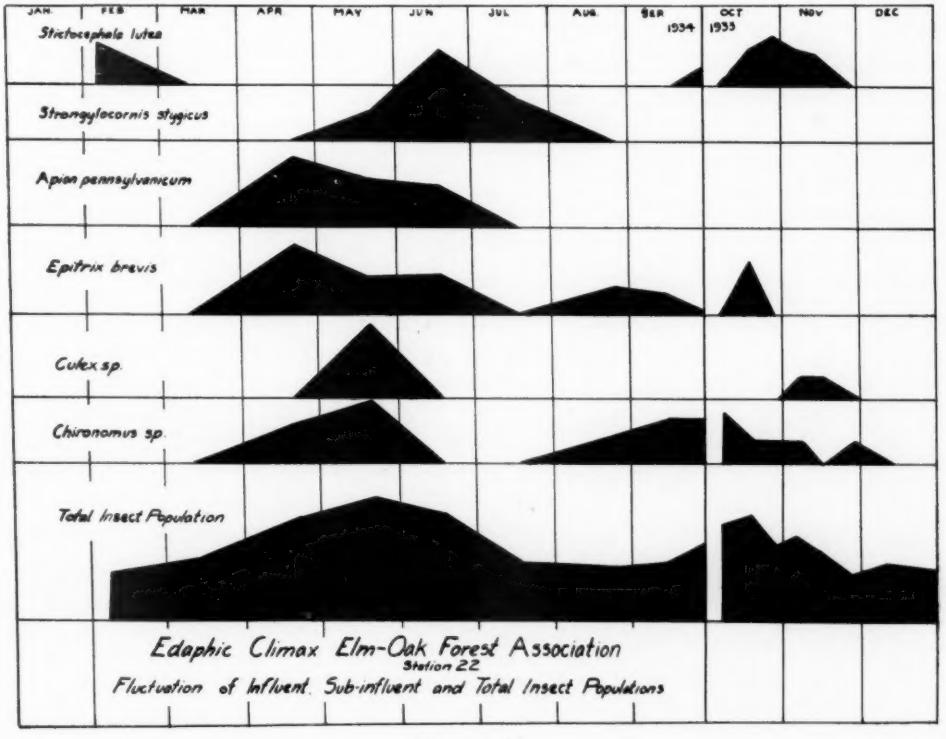

FIGURE 33

cessional phase of the problem. Sanders and Shelford (1922) studied migration and stratification of insects and arachnids quantitatively in a pine-dune community over a two months period. Beebe (1916) noted the fauna of four square feet of jungle debris.

With the exception of the work by Baskina and Friedman (1926) no quantitative investigations have been reported dealing with the animal components of river floodplain communities.

Weese (1924) made the first yearly quantitative study of a population as a whole. He used the method of random sampling, noted the seasonal and stratal abundance of ecologically important species with reference to migration, and characterized the communities of the Illinois Elm-Maple forest, in which he worked.

Smith-Davidson (1930) reported the results of an investigation of the tree layer society of the same forest studied by Weese (1924) and showed that the presociety of the forest has a permanent tree layer of animal species not taken in lower strata. Later (1932) she discussed food and food relations, the effects of seasonal variability, and concluded that the seasonal appearance of a given species is not fixed, and that such a species may appear for example, during the aestival one year, and the serotinal period the following year. The relative variability within the total populations of seral stages remains practically constant throughout the year. She also concluded that the number of seasonal and incidental species decreases as the succession proceeds toward the climax, and that the number of perennial dominants increases toward the climax. Her observation (1932) that the number of seasonal and incidental species decreases as the sere proceeds toward the climax is substantiated by the present data.

Blake (1931) compared his work (1925) with that of Weese (1924), and Smith-Davidson (1930). He drew no specific conclusions, but expressed the opinion that the studies were of too short duration to be of value in evaluating the importance of animal species in the communities in question.

It is no doubt true that the peaks of community populations vary both in height and time of appearance from year to year. But when the behavior of insect populations in forests as widely separated as the University Woods, Urbana, Illinois, and the edaphic climax association considered here agrees not only in the time of reaching maxima, but even to the presence of the same influent species the author is strongly inclined to feel that the "high spots" at least in the behavior of insect populations may be revealed by the study of a single yearly cycle.

Shackleford (1929) studied the animal communities of an Illinois prairie and found two animal presocies present throughout the year in subclimax prairie. Five seasonal socies were also present in the yearly cycle in each of the presocies. She reached the same conclusion as Smith-Davidson (1928) that the constituent animals of one presocies present one year may be absent the succeeding year. Both found that the relative variability within the total population of seral stages remains practically constant throughout the year. If this is true the appearance of one or more component species a season ahead or behind its date of appearance the previous year would play a small

part in the fluctuation of the population as a whole and the relative importance of the population at each successive season through successive years would remain practically constant.

Brown and Shackleford (1929) compared the autumnal invertebrate population of a prairie area in two successive years and found that its composition varied because of a variation of all groups rather than of a few species. This lends considerable support to the view that the fluctuation of a population may vary from year to year at the same season, but the relation the component species bear to each other and to the population as a whole is a rather constant ratio.

Townsend (1928) found spring and fall maxima in the dipterous and other insect components of an artificial grove. His findings agree rather closely with the behavior of the insects in the climax forest association and the cottonwood parkland associes on the Canadian River floodplain.

Bird (1930), with his researches on the communities of the aspen parkland in central Canada showed spring and fall maxima, and an early spring minimum. The aspen parkland is subclimax and his findings agree with the writer's data for the cottonwood dune parkland.

Brown (1931) compared the animal population of a Missouri oak forest and a similar forest situated near the ecotone between forest and prairie in central Oklahoma and found little evidence that animals migrate from prairie to woodland for purposes of hibernation during the winter. Her work considered upland communities, which may possibly account for the discrepancy between her conclusions and the results of this investigation. She found spring and fall maxima in the populations of the communities studied, which in the writer's opinion might be an indication of a migration into the woodland in the fall, while the spring maximum could be caused in part by animals coming out of hibernation.

SUMMARY

The floodplain sere begins on the first level of the floodplain and the initial associes are transitory seldom enduring more than a year. The rapidity with which succession proceeds is due to the rapid accumulation of wind blown sand that raises the undisturbed portions of the first level to second level height during a single year.

The complexity of the sere is due primarily to physiographic agencies and to variations in the time of year at which initial communities are formed, and secondarily to the type and amount of vegetation arising in mid-seral communities on the first and second levels.

By the time an area grows physiographically to the height of the third level there is a segregation of co-dominants into communities which will be followed by (1) subclimax prairie, (2) sub-climax dune prairie, (3) sub-climax cottonwood parkland, or (4) sub-climax cottonwood dune parkland when it approaches the height of the fourth level.

These sub-climax associes are at present being held static by coaction; their attainment of a climax condition is being retarded by the heavy grazing to which the areas have been subjected for the past decade. If left alone the parkland sub-climaxes will in time invade the prairie sub-climaxes, and in turn be followed by edaphic climax forest.

Because of the invasion of the floodplain by *Tamarix gallica* on the second and third levels facies have been established in many associes and *Tamarix consocics* have been formed. The writer believes that the plant will in time form pure edaphic climax stands on the fourth level of the floodplain.

The insect population of the climax association showed definite maxima in May and October, the sub-climax parkland dune associes in May, July, and October, and the level parkland in July and October. The sub-climax prairie showed the fall peak and an indefinite maximum in July. The populations of the older mid-seral communities were characterized by peaks in April, July, and October, with the greatest population numbers in mid-summer. The younger mid-seral communities were less inclined to show definite population maxima.

The population of the *Tamarix Consocies* was by far the greatest of any community studied and reached an enormous maximum in July, but showed no other maxima. The behavior of its insect population definitely showed that it is distinct from all other communities in the sere and has no close affinities with any associes dominated by native plants.

ACKNOWLEDGMENTS

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AN ECOLOGICAL STUDY OF CEDAR GLADE INVERTEBRATES NEAR NASHVILLE, TENNESSEE

By

ADELPHIA MARTHA MEYER

Wilson Teachers College
Washington, D. C.

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AN ECOLOGICAL STUDY OF CEDAR GLADE INVERTEBRATES NEAR NASHVILLE, TENNESSEE

INTRODUCTION

There are perhaps not more than a dozen well marked types of rock-outcrop vegetation in the eastern United States, that is omitting, of course, consideration of precipitous cliffs (Harper 1926). Rocks are common enough in most parts but the rocky areas are not sufficiently large to establish any peculiar species. One of the most interesting types of flat rock areas is that of the cedar glades of Middle Tennessee.

The unusual nature of the cedar glades offers a striking contrast to the surrounding area. Ecologically they represent an edaphic region in the midst of another region which given time appears to develop characteristically into a maple-beech climax with oak-hickory as a rather constant subclimax. This edaphic area of approximately three hundred square miles, about five per cent of the total area of the central basis of Middle Tennessee, has persisted as a region characterized by a subclimax of red cedar (*Juniperus virginiana* L.) where sufficient soil occurred. The groups of cedars are separated from one another by open rocky glades from which the region receives its name. On the whole the soil is extremely shallow and in many places there are large areas of exposed limestone of the Lebanon Formation (Galloway 1919).

The general region which includes the cedar glades has been carefully studied from the view of geology (Safford 1869; Wilson 1935; Foreste 1903; Ulrich 1911; Bassler 1932; and Galloway 1919); and of soils (Smith and Bennett 1904; Mooers and Coryell 1924). The vegetation has also been studied (Gattinger 1901; Harper 1926; Picklesimer 1927; and Freeman 1933). Freeman's paper, *Ecology of the Cedar Glade Vegetation near Nashville,* Tennessee, published in 1933, was a most careful study of the vegetation and environmental factors as related to the different plant habitats. However, only one group of animals, birds, has been studied in the cedar glades (Schultz 1930).

The purpose of the present study was to determine the kind of invertebrates in the cedar glades. Environmental factors, temperature, relative humidity, and evaporation were considered in order to present more clearly the conditions under which the animals were found. It was not the purpose to analyze the relative effects of such environmental factors on the animals found.

The work was carried out under the supervision of Dr. Jesse M. Shaver of George Peabody College for Teachers, Nashville, Tennessee. Acknowl-

edgment is here given for his interest and suggestions during the progress of the study. The author classified all animals as completely as possible. All determinations, however, were checked by authorities. Thanks for taxonomic aid are due the following: Dr. W. M. Barrows, Ohio State University, spiders; Dr. Henry W. Olson, Mansfield Pennsylvanian Teachers College, earthworms; Dr. R. A. Hefner, Miami University, myriapods; Professor Clyde A. Dennis, Tusculum College, Greeneville, Tennessee and Dr. Lawrence Wesson, United States Bureau of Entomology and Plant Quarantine, ants; Dr. Paul Bartsch of the Smithsonian Institution, snails; Dr. Harold Morrison and Dr. C. F. Muesbeck of the Division of Insect Identification of the United States Department of Agriculture, insects. Acknowledgment is given to the owners of the area of study and to the people of the community for their general courtesy and to Miss Helen Schultz and other friends who gave various assistance during the course of study.

DESCRIPTION OF AREA STUDIED

Location and Physiography

The area selected for study is located thirteen miles southeast of Nashville, Tennessee, on United States Highway 70 Alternate, in the angle formed by the highway and Hobson Road. It lies between parallels 36°03′ and 36°02′ north latitude and meridians 86°36′ and 86°37′ west longitude. The elevation of the area ranges from 600 to 640 feet above sea level. The physiognomy is shown in Figure 1. The open glades, shrubs and cedar forests are the habitats in which animal collections and weather observations were made.

Geology and Soil

The rocks of the cedar glades are thin flaggy, fossiliferous, dove-colored limestone. They belong mostly to the Lebanon Formation (Galloway 1919), which is made up of layers of thin broken slabs of dense limestone, separated by thin films of shale. The limestone weathers rapidly by freezing and thawing and by solution of rain water and ground water charged with carbon dioxide. Weathering is mainly at and near the surface, and the soluble part of the rock is dissolved and carried away (Galloway 1919). The residue from the weathered Lebanon limestone is very fine and light, and a small percentage of oil makes the particles more buoyant. The numerous bedding planes and the inclination of the strata favor the lateral movement of the ground water. Therefore the transportation of the decomposed rock is nearly as rapid as weathering takes place (Mooers and Coryell 1904).

When the glades have become so nearly level that most of the rain water runs into the rock and the remainder flows off very slowly, then the residual clay accumulates and forms soil. After the soil accumulates to a depth of five or six inches, freezing and thawing become inefficient in breaking and

loosening the rock, and weathering is then wholly by solution and at a much lower rate. The soil over the Lebanon limestone is never deep. The average depth is probably less than a foot, although accumulations of wash from higher places may occur three or four feet deep (Galloway 1919).

The soil of the cedar glades represents the stony phase of the Hagerstown loam, and consists of the relatively insoluble materials which are left behind after the limestone has gone into solution (Smith and Bennett 1904). Figure 2 shows the location of the area studied with respect to soil types on a small portion of the soil map copied from Smith and Bennett.

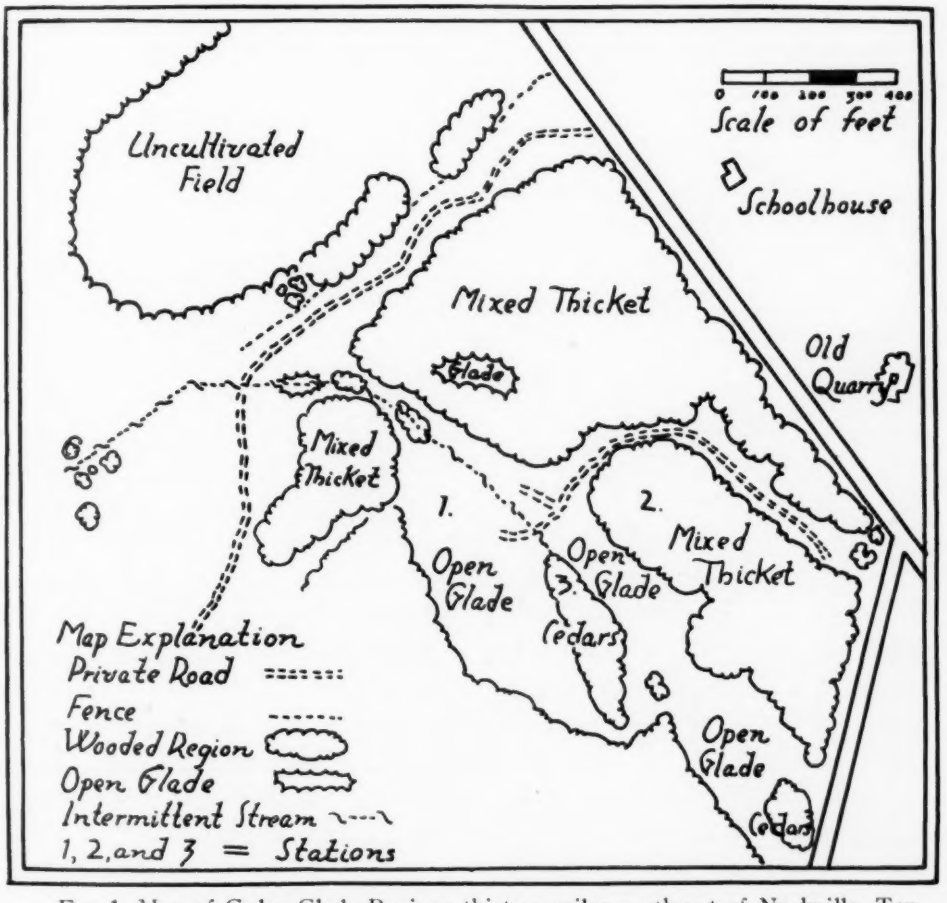

FIG. 1. Map of Cedar Glade Region; thirteen miles southeast of Nashville, Tennessee. Drawn by Helen Houser Schultz.

Freeman (1933) determined the variation and extremes of the hydrogen ion concentration of the soil in the same area. The greatest range found was a pH of 5.95 in the Juniperus woods to a pH of 8.11 in the Isanthus-Hypericum aspect society quadrat. In general he found that the soils were more acid in the Juniperus woods than in the open glades. He concluded that the pH of the soil was not a very important factor in the distribution of plant life in the cedar glades.

The area is drained by a temporary stream which connects in the rainy weather with Stone River (Figs. 1 and 2).

CLIMATE AND WEATHER

Climatological data summarized for the year (Jones 1930) as determined at Sky Harbor, about ten miles from the cedar glades studied, follows. The annual mean temperature was 59.8° F. The highest temperature was 108° F. on July 28, and the lowest was -5° F. on January 18. The last killing frost occurred on April 24 and the first one on October 22. The total precipitation for the year was 37.26 inches. The greatest monthly precipitation was 5.27 inches in March and the lowest was 0.97 inch in June. The total snowfall was 5.5 inches. The number of rainy days was 103. The prevailing wind direction was southwest.

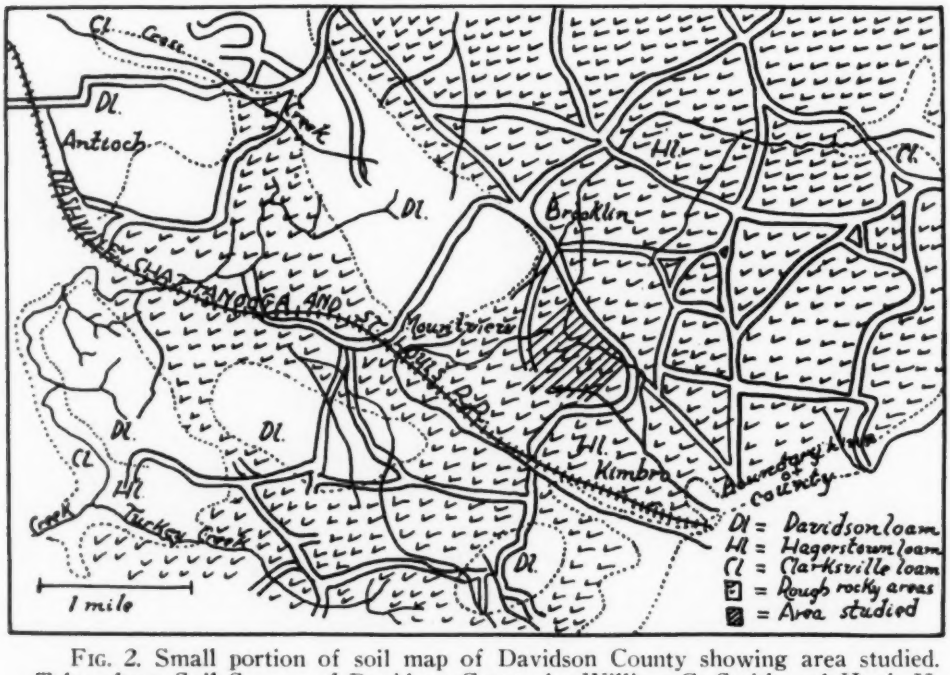

FIG. 2. Small portion of soil map of Davidson County showing area studied. Taken from Soil Survey of Davidson County by William G. Smith and Hugh H. Bennett, 1903.

The year 1930 can hardly be considered as typical. This year will be remembered as one with periods of intense heat and extreme drought. The mean temperature for July was the highest on records for all months. The precipitation averaged below the normal in all but three months. June was the dryest on record in the state and July and August were also very dry. The annual precipitation for the state, 39.80 inches, was 10.26 inches below the normal and the least total amount received during forty-seven years of record. The average amount of sunshine was 58 per cent of that possible. The highest percentage for any month was 81 in June; the lowest was in December with 41 per cent (Jones 1930).

Additional weather data for the area of the cedar glades studied will be found in another section.

VEGETATION

The vegetation of the cedar glades has been carefully studied by Picklesimer (1927) and Freeman (1933). A general description based on Freeman's work follows. Several distinct stages in plant succession were evident. The slabs of limestone in the open habitats provided very xerophytic conditions, where only crustose lichens were found. Some mosses and some very conspicuous spring annuals, such as stonecrop (*Sedum pulchellum* Michx.) and Pitcher's sandwort (*Arenaria patula* Michx.) were in places where small amounts of soil had accumulated. In places where soil was deeper annuals which grow later into the summer were found. They were rush grass (*Sporobolus vaginiflorus* Wood), daisy fleabane (*Erigeron ramosus* Walt.), *Croton monanthogynus* Michx., brome (*Bromus commutatus* Schrad.), panic grass (*Panicum Gattingeri* Nash.), milk purslane (*Euphorbia maculata* L.), *Ruellia ciliosa* Pursh and false pennyroyal (*Isanthus brachiatus* L.). St. John's-wort (*Hypericum sphaerocarpus* Michx.) and prairie clover (*Petalostemum foliosum* Gray) were the most characteristic perennials of the rocky glades.

Three plants having hydrophytic tendencies were also found in the open glades. These were of short duration in the spring. Conspicuous gelatinous Nostoc colonies were found in wet places where the soil was very shallow. Quillwort (*Isoetes Butleri* Engelm.) and *Leavenworthia stylosa* A. Gray were found in soils well saturated with water. However, the latter occurred on somewhat drier soils than the former.

The open glade in which Station 1 was located was elongated with a temporary stream and shrubs on the north and east. A hardwood forest bounded it on the west and southwest and a cedar forest on the southeastern portion.

Station 2 was in a shrub area. This region resembled a trapezium in shape and was surrounded by narrow glades on all sides. On the west it was bounded by a long glade which was a continuation of the open glade studied. The long narrow glades on the northern and eastern side separated this region from a similar shrub region. A wagon road ran through these glades. The shrub stage was characterized by coral-berry (*Symphoricarpos orbiculatus* Moench.), wild privet (*Adelia ligustrina* Michx.) and sumach (*Rhus canadensis trilobata* Gray). Other plants found in this stage were henbit (*Lamium amplexicaule* L.), bedstraw (*Galium pilosum* Ait.), mist-flower (*Eupatorium coelestinum* L.), and panic grass (*Panicum scoparium* Lam.).

Station 3 was in the cedar forest. This was narrow and surrounded by open glades. The glade at the southern end was extremely narrow and separated the cedar from a hardwood forest. A little stream bounded the region on the northeastern side. This forest consisted primarily of red cedar (*Juniperus virginiana* L.). Occasionally honey locust (*Gleditsia triacanthos*

L.), hackberry (*Celtis mississippiensis* Bosc.), winged elm (*Ulmus alata* Michx.) and pignut hickory (*Carya glabra* Mill.) were found. A scanty undergrowth sometimes consisted of a few coral-berry bushes (*Symphoricarpos orbiculatus* Moench.), wild privet (*Adelia ligustrina* Michx.) and an occasional paper mulberry (*Broussonetia papyrifera* L.). Wild oatgrass (*Danthonia spicata* L.) was common. The most characteristic herbs were violet wood sorrel (*Oxalis violaceae* L.), sedge (*Carex grisea* Wahlenb.), aster (*Aster ericoides* L.), mist-flower (*Eupatorium coelestinum* L.), *Croton monanthogynus* Michx., savory (*Satureja glabella* Michx.), false pennyroyal (*Isanthus brachiatus* L.), beard grass (*Andropogon virginicus* L.), daisy fleabane (*Erigeron ramosus* Walt.), Roman wormwood (*Ambrosia artemisiifolia* L.), and plantain (*Plantago aristata* Michx.).

METHODS

Classification of Habitats

Having selected the area for study, it was necessary to classify the habitats within it. The cedar glades were characterized by three distinct habitats: (1) open habitats in the glades, (2) red cedar forest habitats, and (3) shrub habitats. In the course of this study these three types are called respectively: Open Habitat, Cedar Habitat, and Shrub Habitat. These habitats were described in the preceding section.

Extent and Nature of Field Work

Field work started on October 5, 1929 and was carried on each Saturday through November 15, 1930, making the period of study more than thirteen consecutive months. The number of hours spent each Saturday in the field was either about eight, for the author when working alone, or about five when an assistant was present. Each Saturday temperature and evaporation readings were taken. There were, however, seven Saturday's, November 16, December 7, December 21, January 18, March 1, April 5, and September 13 when heavy snow or rain and one instance of illness made animal collecting inexpedient. Field work was devoted to the study of environmental factors of the habitats and the actual collection of invertebrates.

Instrumentation

The environmental factors studied were temperature, relative humidity, and evaporation. In the study of temperature all the thermometers used were calibrated against a certified standard Fahrenheit thermometer. Tycos Sixe's type maximum and minimum thermometers were placed in the Open Habitat, Shrub Habitat and in the Cedar Habitat. In the Shrub Habitat the thermometer was attached to a small cedar tree at the surface of the ground. In the Cedar Habitat the thermometer was attached to a medium sized cedar tree at the surface of the ground. Several thermometers were stolen from

the Open Habitat, so it was necessary to place one in an isolated cedar tree in an open glade as a substitute for a typical Open Habitat station. This thermometer was placed eight feet from the ground. None of the thermometers were placed in thermometer shelters such as are used by the United States Weather Bureau. Instead they were placed on the north side of the trees selected. Each thermometer was read and set each week on Saturday at noon. In this way, the maximum and minimum temperatures of each week were obtained. From these readings the weekly mean temperature was also found by dividing the sum of the weekly maximum and minimum by two. It is recognized that temperature readings, taken as these, were a very poor substitute for continuously recorded temperatures taken by a thermograph. Thermographs were too expensive to place in an area where instruments disappeared so readily, and since it was impractical to visit the area daily, the method described was selected.

In addition to reading the maximum and minimum thermometers each Saturday, wet and dry bulb readings of the thermometers were taken at noon in each habitat. Two chemical Fahrenheit thermometers were used. A small rectangular piece of muslin thoroughly wet with distilled water was wrapped around the bulb of the one thermometer and tied by a thread. Both thermometers were held separated from each other in the right hand and swung back and forth rapidly until a constant reading was obtained. The wet bulb was always held beneath the dry one so that any accidental dropping of water would not modify the reading of the dry thermometer. The readings were taken at about three feet from the ground and also as near the surface as possible. Several readings were taken at each of the levels and these averaged in order that representative readings would be obtained. The readings were started at 11:45 A.M. and completed by 12:15 P.M. The average of the readings was twelve o'clock.

From the Weather Bureau located at Nashville, thirteen miles distant, barometric readings were obtained. With these readings and the difference between the wet and dry bulb readings, the relatives humidities of the three habitats at the time of the temperature readings were determined by using Psychrometric Tables by C. F. Marvin (1915).

Atmometers have proved quite successful in measuring evaporation rates. Since the evaporation rate tends to give the integrated effect of humidity, temperature, light, and wind, spherical porous clay-cup atmometers devised by Livingston (1915) were used in this study. Black and white atmometers were placed so that each bulb was about twelve inches from the ground in the Cedar Habitat and in the Shrub Habitat. In the Open Habitat atmometers were destroyed several times so it was necessary to place two in the same cedar tree in which the maximum and minimum thermometer was placed, instead of trying to maintain them in such an open spot.

A black atmometer was placed with a white one in order to give some measure of the radiant energy of the habitats. The black bulbs absorb more radiant energy than the white ones and consequently give higher evaporation losses during the day. The difference in the evaporation rates of the white and black bulbs exposed in the same place side by side may be used as an indicator of radiant energy (Burns 1923). The black atmometer bulbs used were white bulbs blackened according to the method developed by McLean (1928).

In order to insure proper working during rainy weather, rainproofing valves as developed by Livingston and Thone (1924) were used in the inlet tubes of the atmometers. A valve consists of a drop of mercury between plugs of glass wool and cotton and inserted in a straight tube. Both white and black atmometers were standardized against standard white and black bulbs of known coefficients, as described by Nichols (1913). The atmometers of unknown coefficients along with the ones of known coefficients were placed on a simple revolving table made out of a bicycle wheel which was made to revolve by an electric fan. The atmometers were filled with one per cent formaldehyde solution which was made with distilled water. The atmometers were weighed before and after revolving on the table. The corrected value of the standard was obtained by multiplying the reading by its coefficient. The coefficient for each unknown was determined by dividing the corrected value of the standard by the reading of the unknown. The atmometers were always standardized just before being placed in the field and just after being removed from the field. The coefficient for the period for each atmometer would be an average obtained just before and just after field exposure. These coefficients, in general, did not vary more than 0.04.

During the first part of the study considerable time was given to the finding of a suitable non-freezing fluid substitute for distilled water for the atmometers during the winter months. After theoretical consideration of some of the alcohols and salts, a mixture of glycerine and one per cent formaldehyde was selected for trial. To each liter of one per cent formaldehyde 1381.185 grams of glycerine were added. That amount lowered the freezing point sufficiently. After routine standardization in the laboratory, the atmometers were placed in the three habitats in the field. These were checked each week and any liquid loss was replaced by adding the same amount of one per cent formaldehyde.

The glycerine mixture did not prove successful in the field. It was thought that failure was caused either by the glycerine clogging the pores or the hygroscopic character of the glycerine. It is rather interesting to note that at the time of this experiment with a non-freezing fluid, Livingston (1929) was also working on the same problem. He, too, failed to get any satisfactory results and concluded that evaporation could not be measured under winter conditions by atmometers.

Starting June 7, 1930, atmometers containing one per cent formaldehyde made with distilled water were used. The formaldehyde was used to prevent bacterial and mold growth in and on the atmometers. Each Saturday all the atmometers were weighed on a mail balance to determine the loss for the week. The average of several weighings was taken. Then more fluid was added and the atmometers weighed several times again and the average taken.

ANIMAL STUDIES

The animals were collected by the following methods: Collecting was done every Saturday. One quadrat one foot square and six inches deep was carefully dug in each of the three habitats. Each was marked off and all macroscopic animals removed from the surface before digging started. The digging was done very slowly and carefully in order that all macroscopic animals might be found. All animals thus found were collected and preserved in alcohol, and later identified. The minimum time for digging a quadrat was always at least an hour and when animals were abundant the period was much longer. Each quadrat was divided into three strata and the animals grouped correspondingly: (1) the top or surface, (2) the two inch stratum which included the animals from under the surface down two inches, and (3) that from the two inch level to a depth of six inches. These were arbitrarily selected.

Since the area was characteristically rocky, many rocks presented favorable habitats for animals of the region. So each Saturday twenty-five rocks were turned over and the invertebrates found were collected. The rocks were always replaced as found. The rocks turned over averaged about seven or eight pounds in weight. Rocks were abundant enough so that those turned over once were marked and not studied again for several months.

In addition to quadrat and rock collecting, sweeps of the open glades and low shrubs were taken. The sweeping was done throughout the entire study with one insect net made of cheesecloth and having an opening with a diameter of eleven inches. The sweeping was not done on any quantitative basis. In addition to routine sweeping, whenever any insects were seen they were pursued and caught if possible.

EXPERIMENTAL DATA

TEMPERATURES OF THE THREE HABITATS

The maximum, minimum, and mean air temperatures for each week of the three habitats have been graphed in Figure 3. This shows synchronism in the decrease and increase of temperatures in the three habitats. The Shrub Habitat had the highest maximum temperatures, the average being 80.31° F. against the average of 75.76° F. for the Cedar Habitat and 75.49° F. for the cedar tree in the Open Habitat. The average maximum temperature of the Shrub Habitat was 4.55° higher than that of the Cedar Habitat and 4.82°

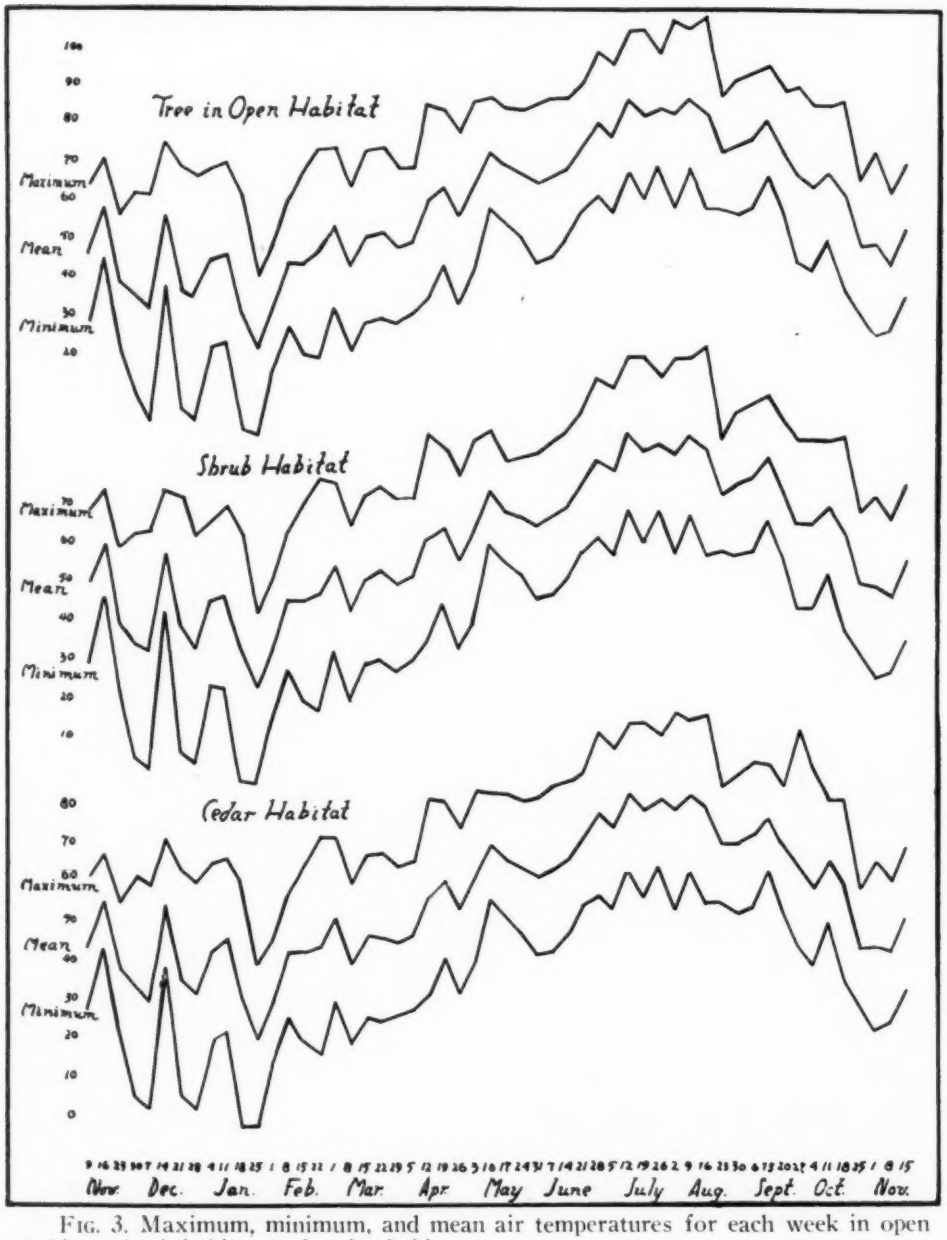

FIG. 3. Maximum, minimum, and mean air temperatures for each week in open habitat, shrub habitat, and cedar habitat.

higher than that in the cedar tree in the Open Habitat. The lowest average minimum temperatures were found in the Cedar Habitat with an average of 36.81° F. The Cedar Habitat was 0.56° colder than that of the Shrub Habitat and 0.90° colder than that of the temperature in the cedar tree in the Open Habitat on the average.

In Figure 4 the noon temperatures of the three habitats are graphed. The curves for the three habitats show a distinct agreement as to the time in the

rise and fall of temperatures. The Open Habitat had the highest average temperatures, being 68.039° F. at the surface and 66.96° at three feet. The next highest was in the Shrub Habitat with 66.91° for the surface and 66.92° for the three foot level. The lowest average temperatures were found in the Cedar Habitat with 65.13° at the surface and 65.16° at three feet.

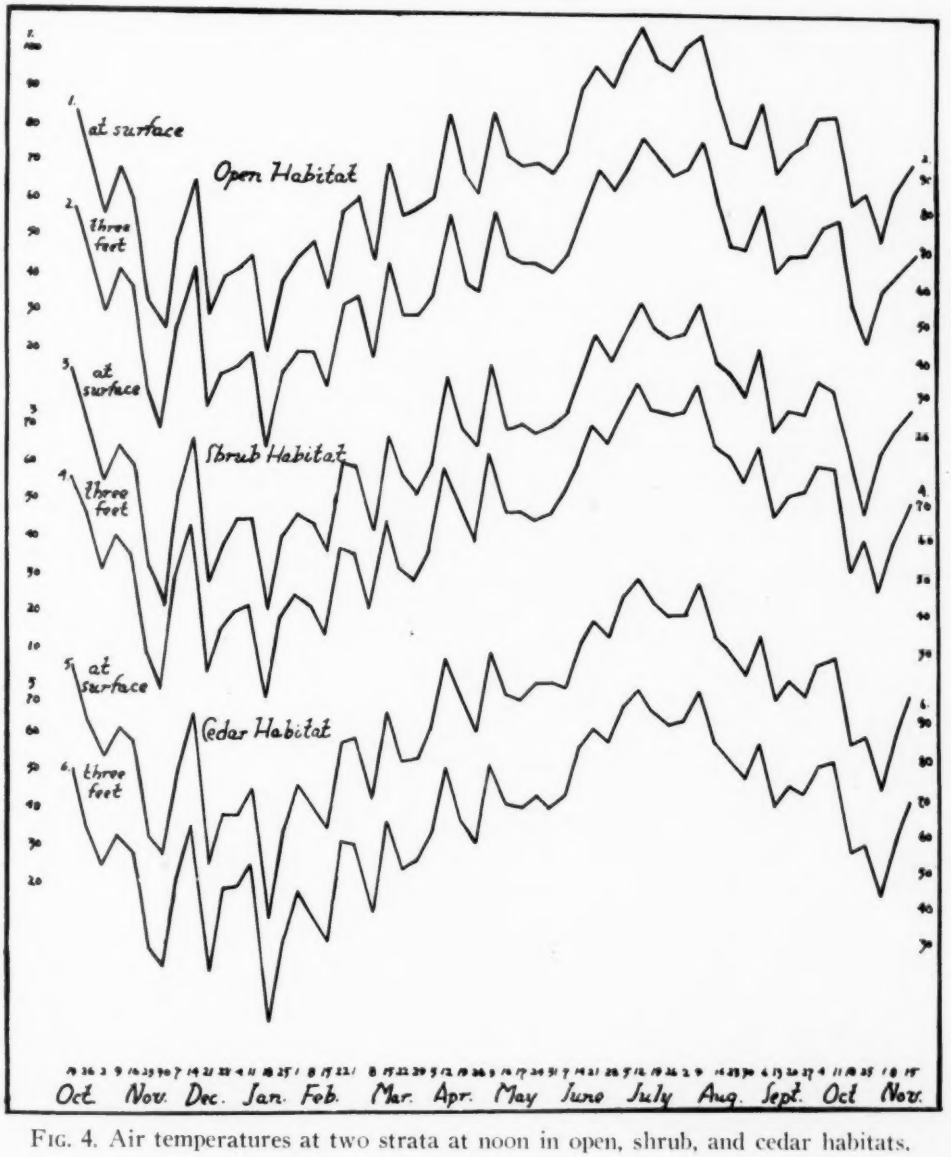

FIG. 4. Air temperatures at two strata at noon in open, shrub, and cedar habitats.

Comparison of the average noon temperatures with the average maximum and minimum temperatures show that the Shrub Habitat had the highest average maximum temperatures while the Open Habitat had the highest average noon temperatures. Both the average maximum and average noon temperatures were lowest in the Cedar Habitat.

RELATIVE HUMIDITIES OF THE THREE HABITATS

The relative humidities at noon for the three habitats are graphed in Figure 5. The curves show the same general trend with but one exception, on January 25 in the Cedar Habitat. The relative humidity was higher in the

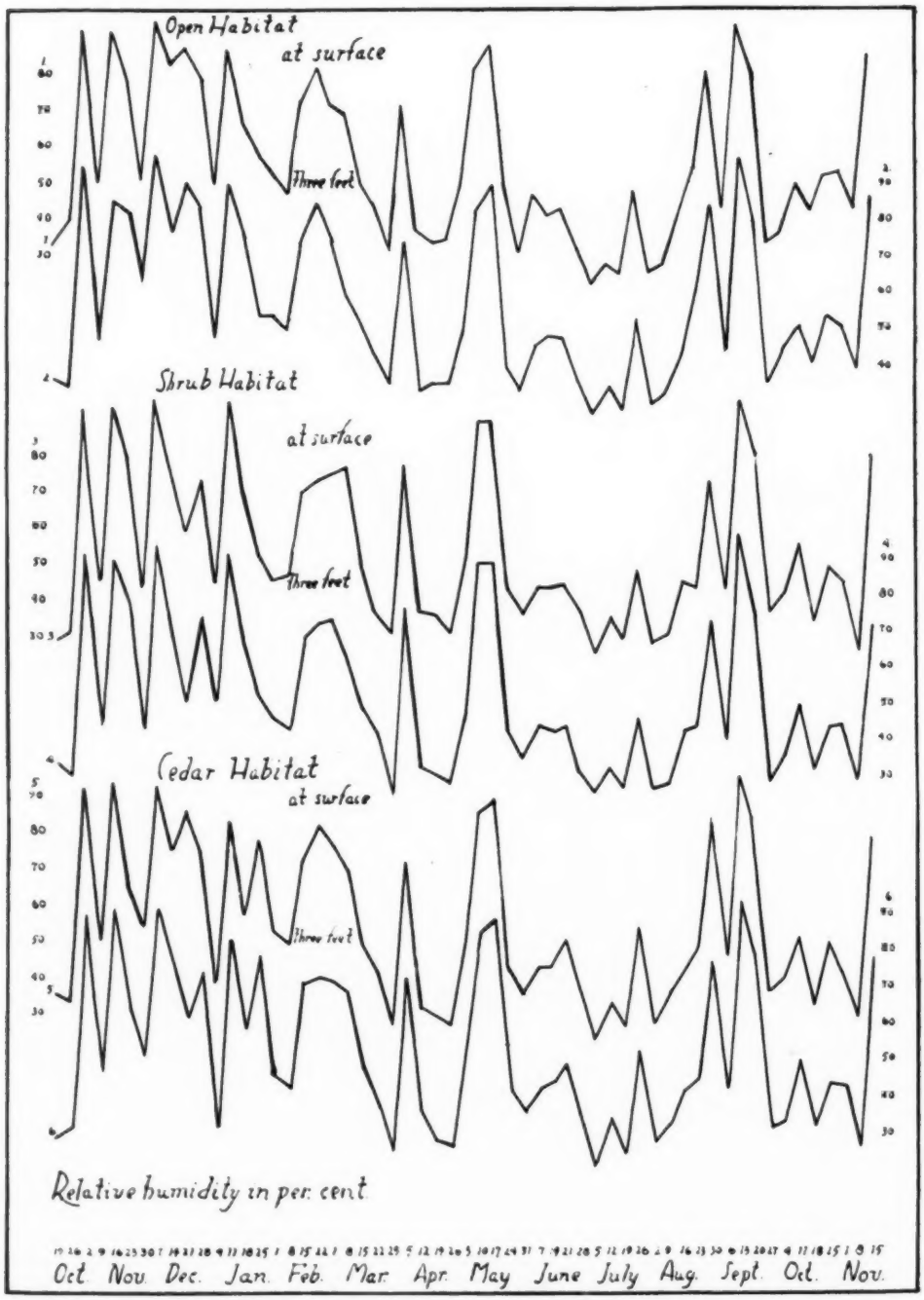

FIG. 5. Relative humidity at two strata at noon in open, shrub, and cedar habitats.

Cedar Habitat than in the other two. The average relative humidities for the three habitats are as follows: in the Open Habitat, 57.40 and 55.92% for the surface and three foot levels; in the Shrub Habitat, 55.09 and 53.80%; and 55.76 and 53.57% for the surface and three foot level in the Cedar Habitat.

EVAPORATION

The average amounts of water evaporated per week for the black atmometers in the Open Habitat, Shrub Habitat, and Cedar Habitat were 6.225, 5.364, and 5.077 ounces respectively. The average amounts lost per week for the white atmometers for the Open Habitat, Shrub Habitat, and Cedar Habitat were 5.655, 4.542, and 5.174 ounces respectively. The greatest amount evaporated by a black atmometer was 11.375 ounces in the Open Habitat during the week ending August 9. The greatest amount lost by a white atmometer was 10.605 ounces in the Cedar Habitat during the week ending July 5.

Figure 6 shows the amounts evaporated from the three habitats. Two conspicuous periods of high evaporation are apparent during early July and early August. Two other periods of moderate evaporation occurred: one late in August and the other early in October. Several accidents occurred in the field to some of the atmometers so data are missing for those dates.

ANIMALS COLLECTED

Three phyla: Annelida, Mollusca, and Arthropoda were represented by the invertebrates collected. Individuals were classified as completely as possible. However, some of the specimens were so immature that determinations could not be made beyond the family or genus. In Figures 7, 8, 9, 10, and 11 the number of species and individuals collected during the course of study have been graphically represented.

Table 1 gives the classification, habitats, and quantitative distribution of the invertebrates found. The following symbols are used: M.F. refers to the number of months during which specimens were collected. R means that specimens were found under rocks. O, S, and C, when followed by 1, 2, or 3, refer to the Open Habitat, Shrub Habitat, and Cedar Habitat respectively. The numbers 1, 2, and 3 refer to the strata in which animals were found: 1 is the top stratum, 2 is the stratum from the top to the two inch level, and 3 is the stratum from the two inch level to the six inch level. S unaccompanied by an integer means that specimens were collected in sweeps. A fraction follows all symbols except M.F. The numerator stands for the number of individuals actually collected in that particular habitat, and the denominator stands for the number of times the species was collected.

One example, *Helodrilus roseus* Savigny, M.F. 4; R, $\frac{3}{2}$; O. 3, $\frac{1}{4}$; S. 1. $\frac{2}{2}$; will be considered. This earthworm was found during four different months. Twice it was found under rocks. One individual was found in the

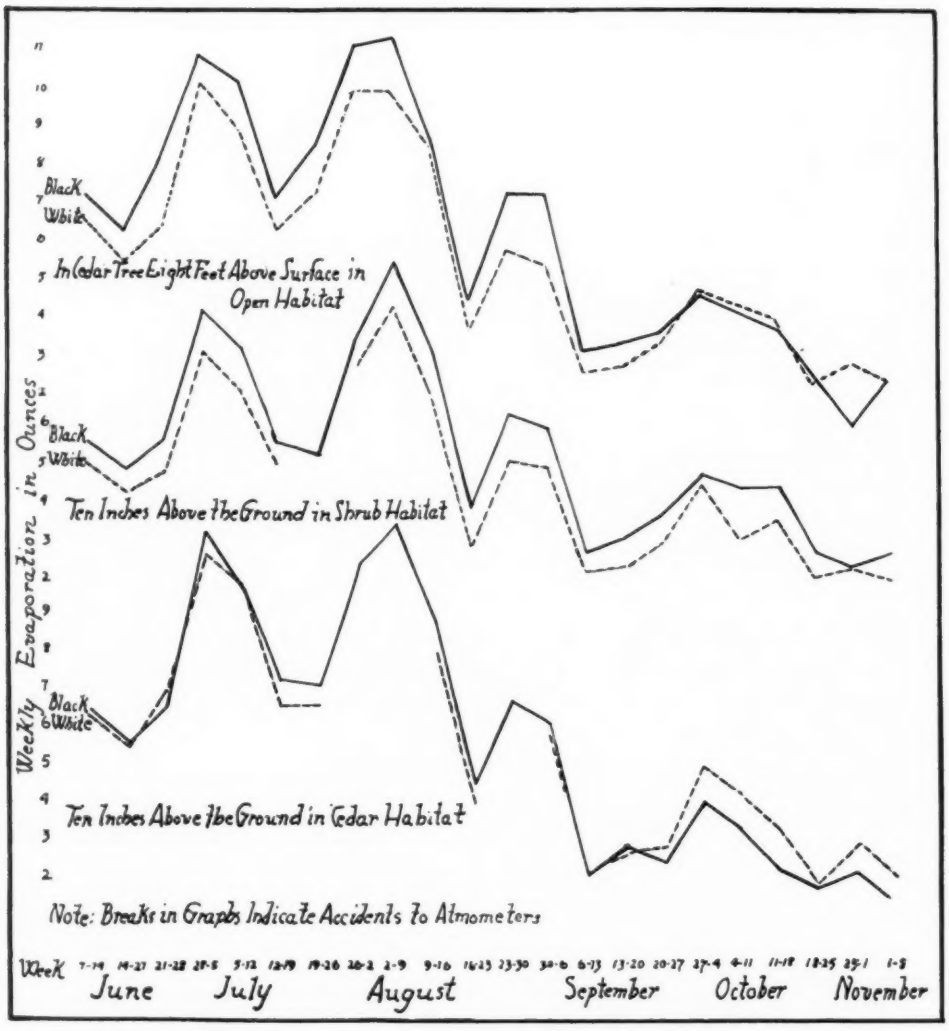

FIG. 6. Weekly evaporation in ounces in the three habitats studied.

third stratum in the Open Habitat and twice single individuals were found in the first stratum in the Shrub Habitat. All together, six individuals were collected.

The major groups of the animals collected will now be considered. The first is the phylum Annelida. In this phylum the two families Lumbricidae and Sparganophilidae were represented each by a single genus Helodrilus and Diplocardia respectively. Considerable difficulty was experienced in the determinations of this group due to the following reasons: first, many of the worms are so immature that even basic morphological characteristics are lacking; second, many worms only show the characteristics of their species during the sexual period; third, many earthworms were obtained in pieces that in all cases could not be successfully put together. Table 1 shows that, in general,

no one species was characteristically found in any one particular habitat. In Figures 7 and 8 the variation in the number of species and individuals found during the course of the study have been indicated. From these figures it appears that the largest number of species and individuals were collected during the winter and spring months and that the least number was found during the summer months. The extreme drought of the summer of 1930 no doubt had some influence on the scarcity of earthworms in the upper strata of the ground.

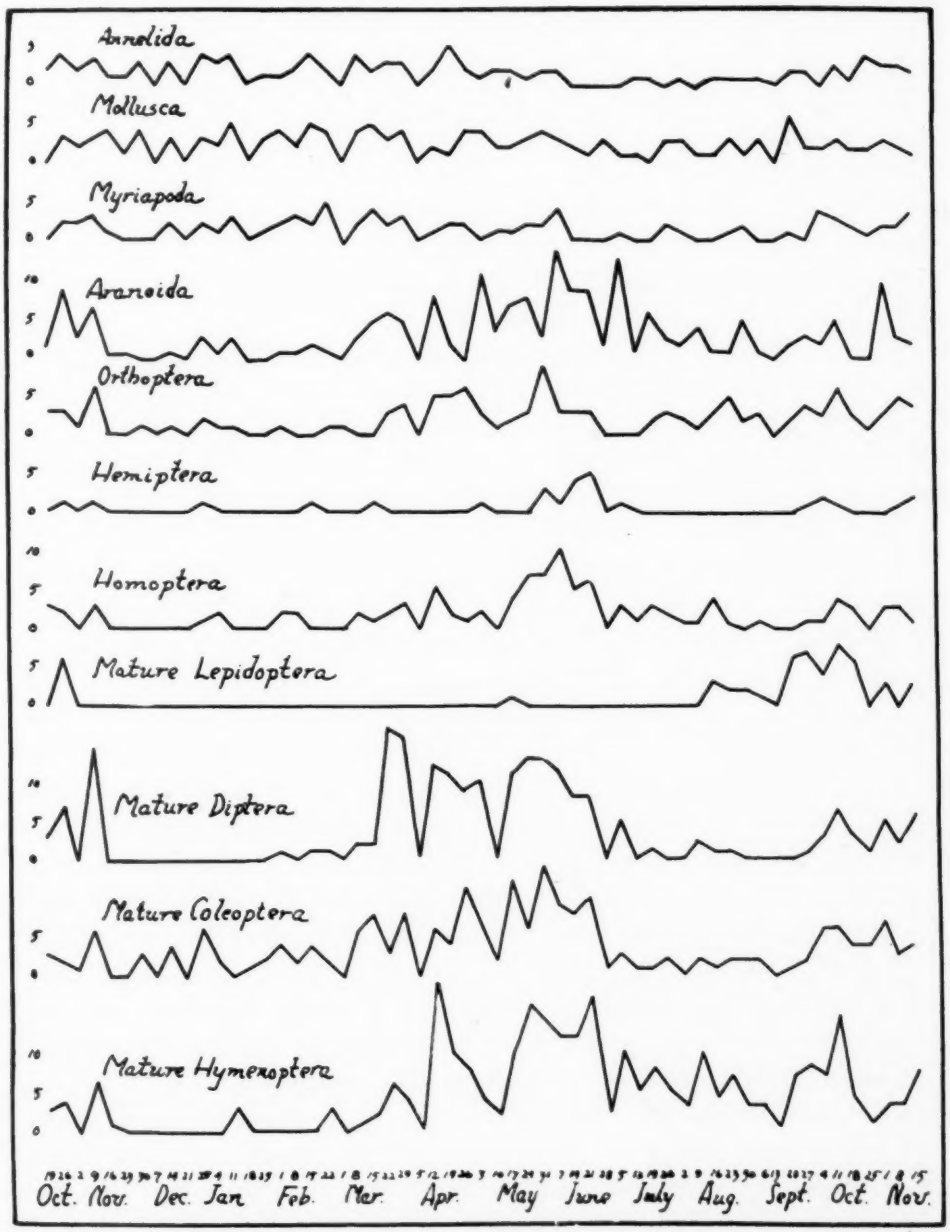

FIG. 7. Number of species of main groups collected during course of study. Collections were not made on Dec. 7, Dec. 21, Jan. 18, Mar. 1, Apr. 5, Sept. 13.

The second phylum, Mollusca, was represented by four families. Two genera, Gastrocopta and Pupoides, of the family Pupillidae were found. The families: Helicidae, Zonitidae, and Helicinidae respectively. Of the seven species collected (Table 1), *Polygyra hirsuta* Say and *Helicina orbiculata* Say were found only a few times. The other five species were found rather abundantly under rocks. The species that was found most was *Zonitoides percallosus* Pils. In general, snails were collected throughout the study. Figures 7 and 8 show that the numbers collected were less in the summer months than at any other time.

The phylum Arthropoda is the next group to be considered. The class Myriapoda with its two orders, Diplopoda and Chilopoda, will be discussed first. Two genera, Spirobolus and Parajulus of Julidae and the one genus Fontaria of the family Polydesmidae represented the order Diplopoda. For the order Chilopoda, the family Scolopendridae with its three genera: Scolopendra, Theatops, and Otocryptops, and the family Dicellophilidae with its genus Dicellophilus and the family Lithobiidae with its genus Lithobius were represented in the collections made. Table 1 shows that both millipeds and centipeds were most abundantly found under rocks. *Dicellophilus limatus* Wood was the only species that was found in the Open Habitat, Shrub Habitat, and Cedar Habitat. Large numbers of individuals of this class were never found, so no striking contrasts are presented by the graphs. However, it may be seen that during the months of October, February, March, and April that the largest numbers were collected.

The next class to be considered is the Arachnoidea. The order Phalangida is the first presented in Table 1. Only two species, *Cynorta sayii* Simon and *Leiobunum ventricosum* Wood, were found and were not abundant.

The order Araneida was represented by twelve families and forty genera. The families were as follows: Avicullariidae, Thomisidae, Clubionidae, Agelenidae, Lycosidae, Oxyopidae, and Attidae. Forty-seven species were found. However, the number of actual species is no doubt nearer fifty-six because there were nine genera represented by forms classified only to the genus, not included in the forty-seven species. The reason for some determinations not being beyond the genus is because of the immaturity of so many of the spiders, and young spiders do not show the morphological characteristics necessary for complete determination.

The family having the largest representation is the Lycosidae. Six genera and nineteen species are represented. *Cyclocosmia truncata* Hentz of the family Avicullariidae was of interest, since it is considered rather rare. Table 1 shows that more spiders were collected under rocks and in sweeps than in the quadrat work. Figues 7 and 8 show that the largest numbers were collected during the spring and summer months and the least during the winter.

Three families of Acarina were represented by the specimens, but since so few were found no further consideration will be given.

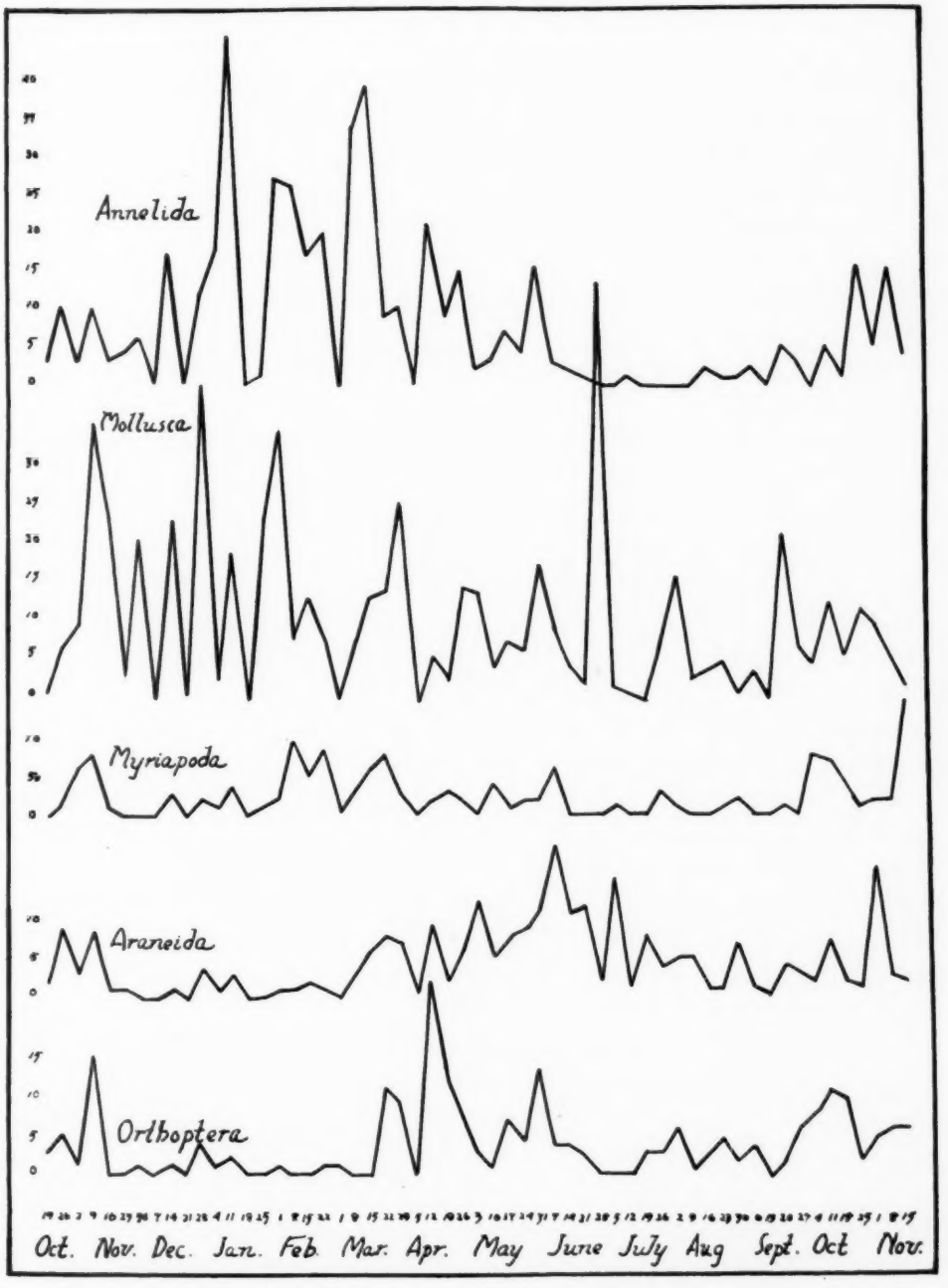

FIG. 8. Number of individuals of main groups collected during course of study. Collections were not made on Dec. 7, Dec. 21, Jan. 18, Mar. 1, Apr. 5, Sept. 13.

The next and largest class is that of the Insecta. The orders will be considered separately. Collembola were represented by three species. In glancing at Table 1 a false impression is given of the quantitative representation of these three species. Many more individuals were caught but lost, many more

were seen but the agility of these minute insects prevented capture of all those seen.

Isoptera were represented by a single species, the well known termite. The quantitative distribution of the species as collected is seen in Table 1.

Individuals of four families of Orthoptera were found. These were in the families: Blattidae, Acrididae, Locustidae, and Gryllidae. Table 1 shows that the cockroaches were found under rocks, that grasshoppers were usually collected in sweeps, and that crickets were found under rocks and in sweeps. In all, twenty-six species were found. Figures 7 and 8 show that the least number of species and individuals were collected during the winter, but it is interesting to note that individuals of this order were found during every month of the year.

Homoptera were represented by six families, twenty-three genera, and twenty-three species. The families were Fulgoridae, Cercopidae, Cicadellidae, Membracidae, Cicadidae, Psyllidae, and Aphididae.

Nine families, twenty genera, and twenty species of Hemiptera were found. The families were Miridae, Nabidae, Reduviidae, Lygaeidae, Neididae, Corixidae, Coreidae, Pentatomidae, and Delphacidae. Figures 7 and 9 show that the largest numbers of species and individuals were found in the early spring, early summer, and fall months.

Neuroptera were represented by a single individual. Two individuals, belonging to the order Mecoptera, were collected.

Lepidoptera showed individuals of the following families: Pyralididae, Geometridae, Saturniidae, Lyonetiidae, Nymphalidae, Lycaenidae, Pieridae, Papilionidae and Hesperiidae. Table 1 shows that all adults were collected in sweeps. By looking at Figures 7 and 9 it can be seen that with one exception adults were collected in August, September, October, and November, while larvae were collected more frequently in the spring months. In all, twenty-four species were found.

The order Diptera was represented by the following families: Tipulidae, Ceratopogonidae, Chironomidae, Mycetophilidae, Bibionidae, Stratiomyiidae, Bombyliidae, Dolichopodidae, Empididae, Lonchopteridae, Pipunculidae, Syrphidae, Conopidae, Tachinidae, Sarcophagidae, Muscidae, Anthomyiidae, Scatophagidae, Borboridae, Sapromyzidae, Ortalidae, Sepsidae, Ephydridae, Oscinidae, Drosophilidae, Agromyzidae. In all, twenty-six families, forty-seven genera, and thirty species were represented. Table 1 shows that most of the adults were collected by sweeps. The largest numbers were collected during March, April, May, June, and November.

Coleoptera were represented by the following families: Cicindelidae, Carabidae, Staphylinidae, Coccinellidae, Erotylidae, Histeridae, Elateridae, Lampyridae, Malachiidae, Cleridae, Scarabaeidae, Cerambycidae, Chrysomelidae, Tenebrionidae, Mordellidae, and Curculionidae. The individuals collected represented sixteen families, fifty-two genera, and fifty-one species.

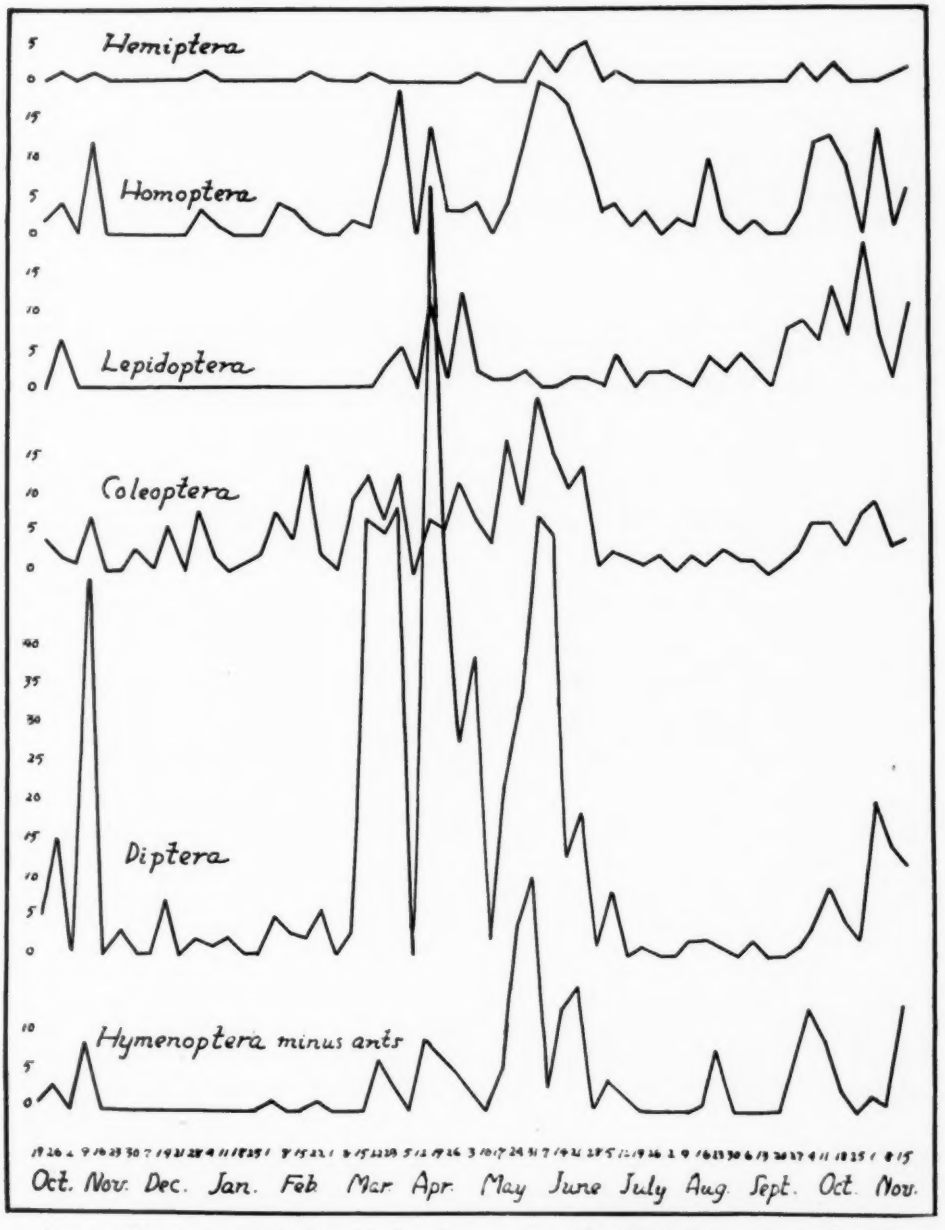

FIG. 9. Number of individuals of main groups collected during course of study.

Table 1 shows that beetles were found in all habitats and that more were found under rocks and on plants. Figures 7 and 9 show that the largest collections were obtained in the spring and early summer months. Members of this order were found during every month. One individual belonging to the rare genus, Anillus, was found.

Of Hymenoptera the following families were found: Tenthredinidae, Vipionidae, Alysiidae, Braconidae, Ichneumonidae, Chalcididae, Mutillidae,

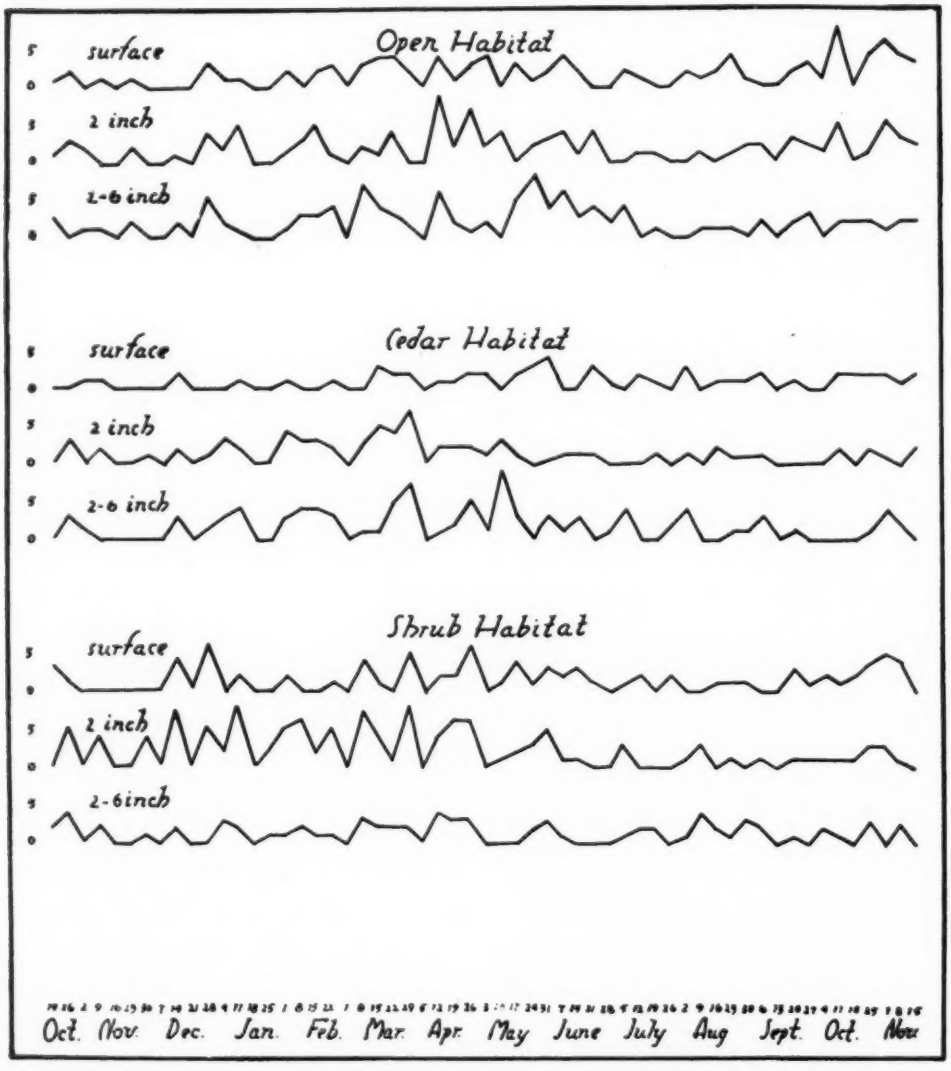

FIG. 10. Number of species found at three levels in three habitats during study.

Vespidae, Sphecidae, Halictidae, Apoidae, Panurgidae, Hylaeidae, Apidae, Melectidae, Andrenidae, and Formicidae. This order was represented by seventeen families, forty-two genera, and forty-five species. From Table 1 it is seen that in general, most of the individuals were collected by sweeps. Figures 7 and 9 show that the least number was collected during the winter. In Figure 9 it was necessary to leave out the ants in the graph because several ant nests were found with several hundred individuals and to show them, the scale of the graphs would have had to be reduced too much.

In Figures 10 and 11 the number of species and individuals found at different levels in the three habitats are graphed. Figure 11 shows that the Open Habitat and the Shrub Habitat had in general more species than the

Cedar Habitat. All three habitats showed a general decrease in the number of individuals in the summer after a rather definite increase in the spring. In Figure 11 the graphs for the Open Habitat and the Cedar Habitat are characterized by great peaks. In the case of the Open Habitat, the finding of an ant's nest was responsible for them, and in the Cedar Habitat ants and

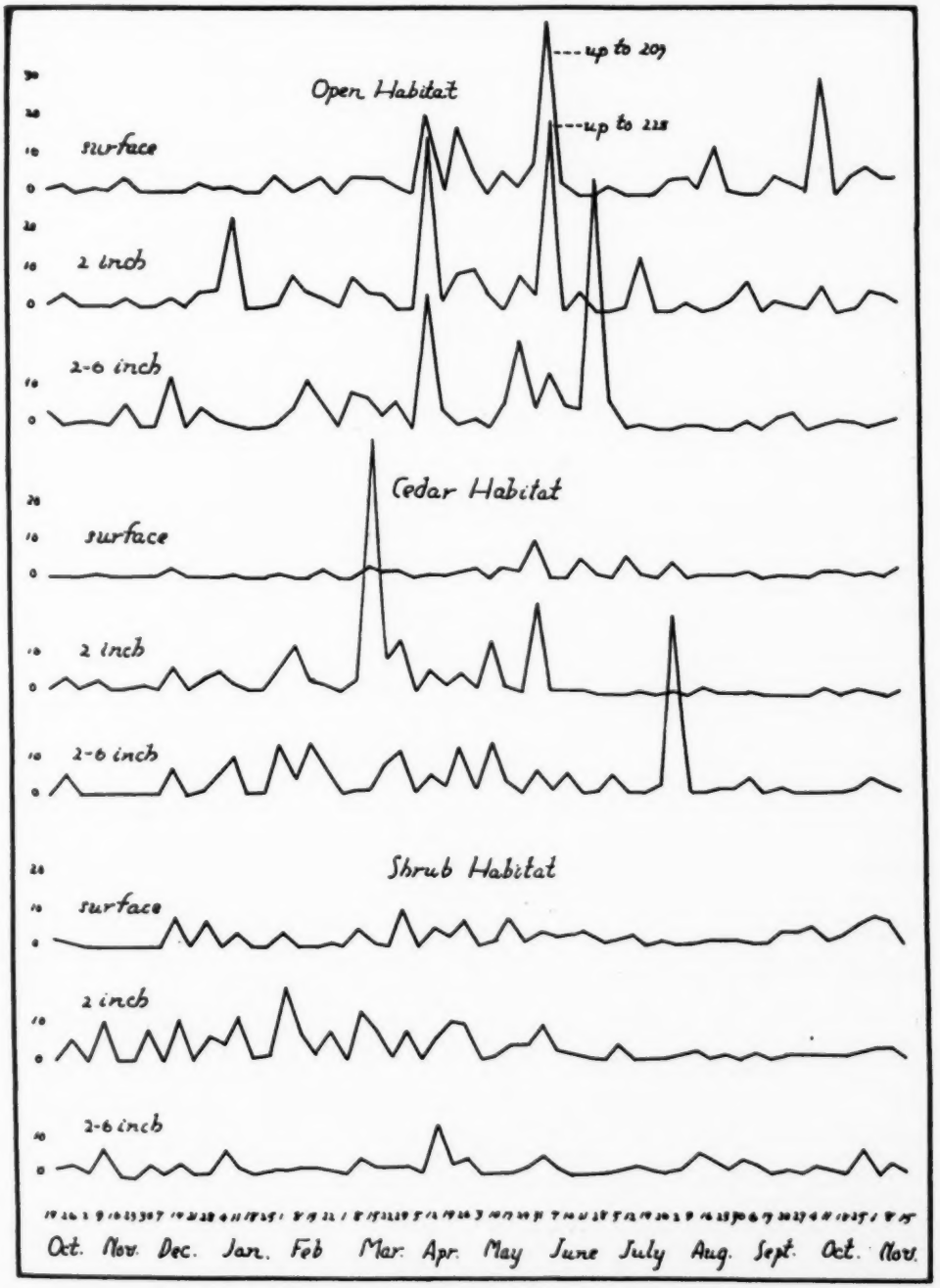

FIG. 11. Number of individuals found at three levels in three habitats during study.

Diptera larvae. It is apparent in Figure 10 that the graphs representing different strata in the same habitat tend to follow the same course, while in Figure 11 there is no similarity between the different strata of the same habitat. The two figures present a rather striking contrast in terms of strata. This is clearly shown in the Cedar Habitat. The graph was low for the surface level and higher in the two representing the other strata. Both Figures 10 and 11 do show that animal life was present during the entire year.

At this point it would be interesting to compare and contrast the animals of the area studied in the cedar glades with those found in the surrounding maple-beach and oak-hickory areas. However, that is not yet possible, for up to the present time, no detailed animal studies have been made of those areas.

TABLE 1

CLASSIFICATION, HABITS, AND QUANTITATIVE DISTRIBUTION OF ANIMALS FOUND

PHYLUM ANNELIDA

Class CHAETOPODA

Order OLIGOCHAETA

Oligochaeta cocoons ..... M. F. 8; O. 2. $\frac{15}{4}$; O. 3. $\frac{10}{4}$; S. 1. $\frac{1}{1}$; S. 2. $\frac{8}{4}$; S. 3. $\frac{4}{3}$; C. 2. $\frac{3}{3}$; C. 3. $\frac{6}{4}$.

Lumbricidae (immature forms) ..... M. F. 9; R. $\frac{2}{2}$; O. 2. $\frac{71}{7}$; O. 3. $\frac{8}{6}$; S. 1. $\frac{6}{3}$; S. 2. $\frac{47}{12}$; S. 3. $\frac{1}{1}$; C. 2. $\frac{62}{10}$; C. 3. $\frac{29}{8}$.

Helodrilus roseus Savigny ..... M. F. 4; R. $\frac{3}{2}$; O. 3. $\frac{1}{1}$; S. 1. $\frac{2}{2}$.

Helodrilus forma trapezoides Duges ..... M. F. 6; R. $\frac{10}{5}$; O. 3. $\frac{1}{1}$; S. 3. $\frac{1}{1}$; C. 3. $\frac{2}{2}$.

Helodrilus tenuis Eisen ..... M. F. 3; R. $\frac{1}{1}$; O. 3. $\frac{1}{1}$; S. 2. $\frac{1}{1}$; C. 2. $\frac{1}{1}$; C. 3. $\frac{1}{1}$.

Diplocardia sp. ..... M. F. 12; R. $\frac{7}{7}$; O. 1. $\frac{2}{2}$; O. 2. $\frac{12}{10}$; O. 3. $\frac{19}{16}$; S. 2. $\frac{4}{4}$; S. 3. $\frac{11}{10}$; C. 1. $\frac{1}{1}$; C. 2. $\frac{4}{4}$; C. 3. $\frac{13}{12}$.

Diplocardia communis Garman ..... M. F. 12; R. $\frac{6}{5}$; O. 1. $\frac{1}{1}$; O. 2. $\frac{4}{4}$; O. 3. $\frac{6}{5}$; S. 2. $\frac{3}{3}$; S. 3. $\frac{8}{6}$; C. 2. $\frac{2}{2}$; C. 3. $\frac{2}{2}$.

Diplocardia ripara Smith ..... M. F. 12; R. $\frac{8}{5}$; O. 1. $\frac{1}{1}$; O. 2. $\frac{16}{10}$; O. 3. $\frac{8}{5}$; S. 1. $\frac{2}{2}$; S. 2. $\frac{15}{12}$; S. 3. $\frac{27}{11}$; C. 2. $\frac{16}{9}$; C. 3. $\frac{28}{11}$.

PHYLUM MOLLUSCA

Class GASTROPODA

Order PULMONATA

Suborder STYLOMMATOPHORA

Gastrocopta armifera clappi St. ..... M. F. 13; R. $\frac{42}{18}$; S. $\frac{1}{1}$; O. 2. $\frac{1}{1}$; S. 1. $\frac{2}{2}$; S. 2. $\frac{2}{2}$; C. 1. $\frac{1}{1}$.

Pupoides marginatus Say.....M. F. 13; R. $\frac{133}{23}$; O. 1. $\frac{4}{2}$; O. 2. $\frac{1}{1}$; O. 3. $\frac{1}{1}$; S. 1. $\frac{1}{1}$; C. 2. $\frac{1}{1}$.

Polygyra hirsuta Say.....M. F. 1; R. $\frac{2}{1}$.

Polygyra monodon aliciae Pils.....M. F. 13; R. $\frac{133}{25}$; S. 1. $\frac{2}{1}$; S. 2. $\frac{3}{2}$.

Polygyra troostianna Lea.....M. F. 12; R. $\frac{42}{16}$; C. 1. $\frac{1}{1}$.

Zonitoides percallosus Pils.....M. F. 14; R. $\frac{174}{40}$; O. 1. $\frac{1}{1}$; S. 1. $\frac{18}{13}$; S. 2. $\frac{34}{15}$; S. 3. $\frac{2}{2}$; C. 1. $\frac{8}{7}$; C. 2. $\frac{7}{5}$; C. 3. $\frac{2}{2}$.

Order PROSOBRANCHIATA
Suborder SCUTIBRANCHIATA

Helicina orbiculata Say.....M. F. 3; R. $\frac{4}{4}$.

PHYLUM ARTHROPODA

Class MYRIAPODA
Order DIPLOPODA
Suborder CHILOGNATHA

Fontaria coriacea Koch.....M. F. 3; R. $\frac{2}{2}$; C. 1. $\frac{1}{1}$.

spirobolus marginatus Say.....M. F. 5; R. $\frac{7}{5}$.

Parajulus sp.....M. F. 2; R. $\frac{5}{3}$.

Parajulus ellipticus Bollman.....M. F. 9; R. $\frac{33}{9}$; S. 2. $\frac{2}{2}$.

Order CHILOPODA
Suborder EPIMORPHA

Dicellophilus limatus Wood.....M. F. 12; R. $\frac{21}{13}$; O. 2. $\frac{3}{3}$; O. 3. $\frac{2}{2}$; S. 2. $\frac{3}{2}$; S. 3. $\frac{1}{1}$; C. 1. $\frac{2}{2}$; C. 2. $\frac{1}{1}$; C. 3. $\frac{5}{5}$.

Scolopendra woodi Meinert.....M. F. 1; R. $\frac{1}{1}$.

Theatops posticus Say.....M. F. 9; R. $\frac{13}{9}$; S. 2. $\frac{1}{1}$; C. 2. $\frac{1}{1}$.

Octocryptops sexpinosus Say.....M. F. 7; R. $\frac{9}{7}$.

Order CHILOPODA
Suborder ANAMORPHA

Lithobius forficatus Linnaeus.....M. F. 12; R. $\frac{33}{20}$; S. 1. $\frac{1}{1}$.

PHYLUM ARTHROPODA

Class ARACHNOIDEA
Order PHALANGIDA
Suborder MECOSTETHI

Cynorta sayii Simon.....M. F. 2; R. $\frac{5}{2}$.

Leiobunum ventricosum Wood.....M. F. 3; R. $\frac{1}{1}$; S. $\frac{3}{3}$.

Order ARANEIDA

Immature spiders.....M. F. 12; R. $\frac{6}{5}$; S. $\frac{7}{6}$; O. 1. $\frac{6}{6}$; O. 2. $\frac{3}{3}$; O. 3. $\frac{1}{1}$; S. 1. $\frac{6}{5}$; S. 2. $\frac{2}{2}$; S. 3. $\frac{1}{1}$; C. 2. $\frac{3}{3}$; C. 3. $\frac{2}{2}$.

Pachylomerus sp.....M. F. 1; O. 2. $\frac{1}{1}$.

Cyclocosmia truncata Hentz.....M. F. 4; O. 1. $\frac{1}{1}$; O. 3. $\frac{3}{3}$; S. 3. $\frac{1}{1}$; C. 1. $\frac{1}{1}$; C. 3. $\frac{2}{2}$.

Dictyna sp.....M. F. 2; R. $\frac{1}{1}$; S. $\frac{2}{1}$.

Gnaphosa sericata L. Koch.....M. F. 2; R. $\frac{2}{2}$.

Theridion sp.....M. F. 2; S. $\frac{2}{2}$; S. 1. $\frac{1}{1}$.

Latrodectus mactans Fab.....M. F. 5; R. $\frac{4}{3}$; S. $\frac{1}{1}$; O. 1. $\frac{1}{1}$.

Asagena americana Em.....M. F. 2; S. $\frac{1}{1}$; C. 1. $\frac{1}{1}$.

Enoplognatha marmorata Htz.....M. F. 1; S. $\frac{1}{1}$.

Ceraticelus sp.....M. F. 1; S. $\frac{1}{1}$.

Epeira pegnia Walch.....M. F. 1; S. 1. $\frac{1}{1}$.

Linyphia sp.....M. F. 1; S. $\frac{1}{1}$.

Linyphia communis Htz.....M. F. 1; S. $\frac{1}{1}$.

Tetragnatha sp.....M. F. 5; S. $\frac{7}{6}$; O. 1. $\frac{1}{1}$.

Tetragnatha straminea Em.....M. F. 3; S. $\frac{4}{1}$.

Marxia stellata Walck.....M. F. 4; S. $\frac{5}{5}$; O. 1. $\frac{1}{1}$.

Mangora gibberosa Htz.....M. F. 1; S. $\frac{4}{4}$.

Acacesia foliata Htz.....M. F. 1; S. $\frac{1}{1}$; C. 1. $\frac{1}{1}$.

Thomisidae immature.....M. F. 2; S. $\frac{2}{2}$; O. 1. $\frac{1}{1}$.

Misumena sp.....M. F. 2; S. $\frac{2}{2}$.

Misumessus sp.....M. F. 1; S. $\frac{1}{1}$.

Misumessus oblongus Keys.....M. F. 3; S. $\frac{6}{5}$.

Misumessus asperatus Htz.....M. F. 2; S. $\frac{2}{2}$.

Oxyptila conspurcata Thorell.....M. F. 1; O. 1. $\frac{1}{1}$.

Xysticus sp.....M. F. 4; S. $\frac{3}{3}$; S. 2. $\frac{1}{1}$.

Xysticus elegans Keys.....M. F. 1; S. $\frac{1}{1}$.

Philodromus pernix Black.....M. F. 1; S. $\frac{1}{1}$.

Gayenna sp. ..... M. F. 3; R. $\frac{1}{1}$; O. 2. $\frac{2}{2}$.

Gayenna saltabunda Em. ..... M. F. 1; C. 1. $\frac{2}{1}$.

Clubiona excepta L. Koch ..... M. F. 1; R. $\frac{1}{1}$.

Castianeira sp. ..... M. F. 1; S. 1. $\frac{1}{1}$.

Agelenidae ..... M. F. 1; C. 1. $\frac{1}{1}$.

Agelena naevia Walck. ..... M. F. 3; R. $\frac{3}{3}$.

Coelotes sp. ..... M. F. 1; R. $\frac{1}{1}$.

Hahnia sp. ..... M. F. 1; O. 2. $\frac{1}{1}$.

Sosippus sp. ..... M. F. 1; R. $\frac{1}{1}$.

Lycosidae (immature) ..... M. F. 4; O. 1. $\frac{1}{1}$; O. 2. $\frac{2}{2}$; S. 1. $\frac{1}{1}$.

Lycosa sp. (immature) ..... M. F. 12; R. $\frac{12}{12}$; O. 1. $\frac{1}{1}$; O. 2. $\frac{1}{1}$; S. 1. $\frac{2}{2}$; S. 2. $\frac{1}{1}$; C. 1. $\frac{5}{5}$; C. 3. $\frac{1}{1}$.

Lycosa coloradensis Bks. ..... M. F. 2; R. $\frac{4}{4}$; O. 3. $\frac{1}{1}$.

Lycosa lenta Htz. ..... M. F. 2; R. $\frac{1}{1}$; S. $\frac{1}{1}$.

Lycosa scutulata Htz. ..... M. F. 2; S. $\frac{1}{1}$.

Lycosa helluo Walck. ..... M. F. 3; R. $\frac{3}{3}$; S. $\frac{1}{1}$.

Lycosa riparia Htz. ..... M. F. 2; R. $\frac{2}{2}$.

Lycosa aspersa Htz. ..... M. F. 1; R. $\frac{1}{1}$.

Lycosa pikei Em. ..... M. F. 1; S. $\frac{1}{1}$.

Lycosa carolinensis Walck. ..... M. F. 1; S. 3. $\frac{1}{1}$.

Lycosa erratica Htz. ..... M. F. 7; R. $\frac{6}{6}$; S. $\frac{1}{1}$; O. 1. $\frac{4}{4}$; S. 1. $\frac{1}{1}$; C. 3. $\frac{2}{1}$.

Lycosa frondicola Em. ..... M. F. 2; R. $\frac{2}{2}$.

Lycosa avara Keys. ..... M. F. 2; R. $\frac{2}{2}$.

Arctosa rubicunda Keys. ..... M. F. 2; R. $\frac{2}{2}$.

Arctosa littoralis Hentz. ..... M. F. 1; R. $\frac{1}{1}$.

Pirata sp. ..... M. F. 2; R. $\frac{2}{2}$.

Pirata minutus Em. ..... M. F. 3; R. $\frac{1}{1}$; C. 1. $\frac{3}{2}$.

Pirata humicolus Mont. ..... M. F. 1; C. 2. $\frac{1}{1}$.

Allocosa sp. ..... M. F. 2; R. $\frac{1}{1}$; S. 1. $\frac{1}{1}$.

Allocosa funera Htz.....M. F. 6; R. $\frac{3}{2}$; O. 1. $\frac{2}{2}$; O. 2. $\frac{2}{2}$; S. 2. $\frac{2}{2}$.

Schizocosa saltatrix Htz.....M. F. 1; R. $\frac{1}{1}$.

Schizocosa ocreata Htz.....M. F. 4; R. $\frac{3}{2}$; O. 1. $\frac{1}{1}$; O. 2. $\frac{1}{1}$.

Pardosa sp.....M. F. 6; R. $\frac{7}{5}$; S. $\frac{1}{1}$; S. 1. $\frac{1}{1}$; C. 1. $\frac{1}{1}$.

Pardosa nigropalpis Em.....M. F. 1; R. $\frac{2}{1}$.

Oxyopes salticus Htz.....M. F. 2; S. $\frac{2}{1}$; S. 1. $\frac{1}{1}$.

Attidae (immature).....M. F. 5; S. $\frac{5}{4}$; O. 1. $\frac{1}{1}$.

Salticus senicus Clerck.....M. F. 2; S. $\frac{2}{2}$.

Phidippus sp.....M. F. 1; S. $\frac{1}{1}$.

Wala mitrata Htz.....M. F. 1; C. 1. $\frac{1}{1}$.

Dendryphantes sp.....M. F. 1; S. $\frac{2}{1}$.

Dendryphantes militaris Em.....M. F. 1; S. $\frac{1}{1}$.

Dendryphantes capitatus Htz.....M. F. 1; S. $\frac{1}{1}$.

Habrocestum sp.....M. F. 1; S. $\frac{1}{1}$.

Habrocestum pulex Htz.....M. F. 1; R. $\frac{1}{1}$.

Phlegra leopardus Peck.....M. F. 1; R. $\frac{1}{1}$.

Pellenes borealis Banks.....M. F. 1; S. $\frac{1}{1}$.

Pellenes coronatus Htz.....M. F. 1; S. $\frac{1}{1}$.

PHYLUM ARTHROPODA

Class ARACHNOIDEA

Order ACARINA

Margaropus sp.....M. F. 1; S. 1. $\frac{1}{1}$.

Dermacentor variabilis Say.....M. F. 4; S. $\frac{2}{2}$; S. 1. $\frac{1}{1}$; C. 1. $\frac{1}{1}$; C. 3. $\frac{1}{1}$.

Eupodoidea (immature).....M. F. 1; R. $\frac{1}{1}$.

Trombidoidea (immature).....M. F. 1; S. 1. $\frac{1}{1}$.

Class INSECTA

Order COLLEMBOLA

Folsomia fimetaria L.....M. F. 1; C. 1. $\frac{2}{1}$.

Pseudosinella violenta Fols.....M. F. 2; R. $\frac{3}{1}$; C. 2. $\frac{1}{1}$.

Entombrya multifasciata Tull.....M. F. 2; R. $\frac{1}{1}$; O. 2. $\frac{1}{1}$.

Order ISOPTERA

Termes flavipes Kollar.....M. F. 9; R. $\frac{135}{7}$; S. 3. $\frac{1}{1}$; C. 2. $\frac{13}{2}$; C. 3. $\frac{47}{3}$.

Order ORTHOPTERA

Ischnoptera deropeltiformis Brunner.....M. F. 2; R. $\frac{2}{2}$.

Parcoblatta pennsylvanica De Gerr.....M. F. 1; R. $\frac{1}{1}$.

Nomotettix cristatus compressus Morse.....M. F. 1; S. $\frac{1}{1}$.

Nomotettix cristatus Scudder.....M. F. 2; S. $\frac{4}{2}$.

Acrydium ornatum Say.....M. F. 5; R. $\frac{1}{1}$; S. $\frac{30}{9}$.

Neotettix bolteri Hancock.....M. F. 1; S. $\frac{1}{1}$.

Paratettix toltecus Saussure.....M. F. 1; S. $\frac{1}{1}$.

Tettigidea lateralis Say.....M. F. 1; S. $\frac{18}{4}$.

Tettigidea lateralis parvipennis Harris.....M. F. 1; S. $\frac{1}{1}$.

Tettigidea prorsa Scudder .....M. F. 1; S. $\frac{1}{1}$.

Dichromorpha viridis Scudder .....M. F. 2; S. $\frac{5}{3}$.

Arphia sp.....M. F. 6; S. $\frac{11}{6}$.

Arphia xanthoptera Burmeister.....M. F. 2; R. $\frac{1}{1}$; S. $\frac{1}{1}$.

Arphia granulata Sassure.....M. F. 3; S. $\frac{4}{3}$.

Arphia sulphurea Fabricius.....M. F. 2; S. $\frac{2}{2}$.

Chortophaga viridifasciata DeGeer.....M. F. 6; S. $\frac{31}{11}$.

Encoptolophus sordidus Burmeister.....M. F. 6; S. $\frac{16}{10}$.

Hippiscus sp.....M. F. 1; S. $\frac{3}{2}$.

Hippiscus rugosus Scudder.....M. F. 6; S. $\frac{10}{7}$.

Dissosteira carolina Linnaeus.....M. F. 6; S. $\frac{7}{6}$.

Spharagemon bolli Scudder.....M. F. 3; S. $\frac{3}{3}$.

Mestobregma thomasi Caudell.....M. F. 4; S. $\frac{6}{4}$.

Melanoplus sp.....M. F. 1; S. $\frac{1}{1}$.

Melanoplus atlanis Riley.....M. F. 5; S. $\frac{7}{6}$.

Melanoplus femur-rubrum DeGeer.....M. F. 3; S. $\frac{5}{3}$.

Melanoplus differentialis Thomas.....M. F. 1; S. $\frac{1}{1}$.

Phaneropterinae (immature).....M. F. 3; S. $\frac{4}{4}$.

Nemobius fasciatus socius Scudder.....M. F. 3; R. $\frac{1}{1}$; S. $\frac{7}{3}$.

Miogryllus verticalis Serville.....M. F. 8; R. $\frac{25}{11}$; S. $\frac{1}{1}$; O. 1. $\frac{1}{1}$; O. 3. $\frac{1}{1}$; S. 1. $\frac{1}{1}$; S. 2. $\frac{2}{1}$.

Gryllus assimilis Fabricius.....M. F. 10; S. $\frac{15}{15}$; S. 1. $\frac{1}{1}$.

Order HOMOPTERA

Homoptera nymphs.....M. F. 4; S. $\frac{10}{9}$; O. 3. $\frac{1}{1}$; S. 1. $\frac{1}{1}$; C. 1. $\frac{1}{1}$.

Ormenis venusta Mel.....M. F. 1; R. $\frac{1}{1}$.

Stenocranus sp.....M. F. 2; S. $\frac{4}{4}$.

Cercopidae nymph.....M. F. 1; S. $\frac{1}{1}$.

Cicadellidae nymphs.....M. F. 8; R. $\frac{2}{2}$; S. $\frac{20}{16}$; S. 3. $\frac{1}{1}$.

Arceratagallia sanguinolenta Prov.....M. F. 1; S. $\frac{1}{1}$.

Agallia constricta Van. D.....M. F. 4; S. $\frac{8}{5}$.

Amplicephalus estacadus Ball.....M. F. 1; S. $\frac{1}{1}$.

Graphocephala versuta Say.....M. F. 2; S. $\frac{6}{3}$.

Kolla bifida Say.....M. F. 1; S. $\frac{1}{1}$.

Draeculacephala mollipes Say.....M. F. 1; S. $\frac{1}{1}$.

Xestocephalus pulicarius Van D.....M. F. 1; S. $\frac{1}{1}$.

Deltocephalus flavicosta Stal.....M. F. 2; S. $\frac{7}{3}$.

Phlepsius superbus Van D.....M. F. 2; S. $\frac{8}{4}$.

Phlepsius irroratus Say.....M. F. 1; S. $\frac{1}{1}$.

Thamnotettix nigrifrons Forbes.....M. F. 1; S. $\frac{1}{1}$.

Acinopterus acuminatus Van D.....M. F. 1; S. $\frac{5}{4}$.

Cicadula divisa Uhler.....M. F. 6; S. $\frac{9}{6}$.

Empoasca sp.....M. F. 2; S. $\frac{3}{3}$.

Exitianus obscurinervis Stal.....M. F. 9; S. $\frac{84}{13}$.

Polyamia inimica Say.....M. F. 1; S. $\frac{1}{1}$.

Polyamia weedi Van D.....M. F. 1; S. $\frac{1}{1}$.

Micrutalis clava Say.....M. F. 3; S. $\frac{10}{4}$.

Publilia concava Say.....M. F. 1; S. $\frac{1}{1}$.

Tibicen sp.....M. F. 13; S. 1. $\frac{1}{1}$; S. 3. $\frac{9}{5}$; C. 2. $\frac{19}{10}$; C. 3. $\frac{28}{13}$.

Tibicen pruinosa Say.....M. F. 1; S. $\frac{1}{1}$.

Trioza diospyri Ashm.....M. F. 1; S. $\frac{1}{1}$.

Illinoia pisi Kalt.....M. F. 1; S. $\frac{1}{1}$.

Myzus persicae Sulz.....M. F. 4; S. $\frac{10}{4}$; O. 1. $\frac{1}{1}$; S. 1. $\frac{4}{3}$; S. 2. $\frac{1}{1}$.

Order HEMIPTERA

Plagiognathus politus Uhl.....M. F. 1; S. $\frac{2}{2}$.

Reuteroscopus ornatus Reut.....M. F. 1; S. $\frac{1}{1}$.

Polymerus basalis Reut.....M. F. 1; S. $\frac{2}{2}$.

Lygus pratensis Linnaeus.....M. F. 2; S. $\frac{3}{3}$.

Nabidae nymphs.....M. F. 1; R. $\frac{1}{1}$.

Pygolampis sericea Stal.....M. F. 1; R. $\frac{1}{1}$.

Melanolestes picipes H. S.....M. F. 1; R. $\frac{1}{1}$.

Melanolestes abdominalis H. S.....M. F. 1; R. $\frac{1}{1}$.

Pselliopus cinctus Fab.....M. F. 1; S. $\frac{1}{1}$.

Lygaeus kalmii Stal.....M. F. 1; S. $\frac{1}{1}$.

Geocoris uliginosus Say.....M. F. 1; S. $\frac{1}{1}$.

Oedancalis dorsalis Say.....M. F. 1; S. $\frac{1}{1}$.

Phlegyas abbreviatus Uhl.....M. F. 1; S. $\frac{1}{1}$.

Myodochus serripes Oliv.....M. F. 2; R. $\frac{2}{1}$; S. 1. $\frac{1}{1}$.

Jalysus spinosus Say.....M. F. 2; S. $\frac{2}{2}$.

Corizus lateralis Say.....M. F. 1; O. 1. $\frac{1}{1}$.

Chelenidea vittiger Uhl.....M. F. 1; S. $\frac{1}{1}$.

Cosmopela bimaculata Thom.....M. F. 1; S. $\frac{1}{1}$.

Hymenarcys nervosa Say.....M. F. 1; R. $\frac{1}{1}$.

Stirellus obtutus Van D.....M. F. 1; S. $\frac{1}{1}$.

Delphacodes sp.....M. F. 2; S. $\frac{2}{2}$.

Sogata furcifera Horv.....M. F. 1; S. $\frac{1}{1}$.

Order NEUROPTERA

Neuroptera larvae.....M. F. 2; O. 2. $\frac{2}{2}$.

Chrysopa sp.....M. F. 1; S. $\frac{1}{1}$.

Order MECOPTERA

Panorpidae larvae.....M. F. 2; S. $\frac{1}{1}$; O. 3. $\frac{1}{1}$.

Order LEPIDOPTERA

Lepidoptera larvae.....M. F. 12; R. $\frac{23}{5}$; S. $\frac{4}{3}$; O. 1. $\frac{14}{11}$; O. 2. $\frac{15}{11}$; O. 3. $\frac{4}{3}$; S. 1. $\frac{13}{7}$; S. 2. $\frac{8}{7}$; S. 3. $\frac{2}{2}$; C. 1. $\frac{2}{2}$; C. 2. $\frac{1}{1}$; C. 3. $\frac{2}{2}$.

Suborder FRENATAE

Crambus trisectus Walker.....M. F. 3; S. $\frac{3}{3}$.

Geometridae larvae.....M. F. 4; S. $\frac{4}{4}$; O. 2. $\frac{1}{1}$.

Euacidalia ossularia Hbn.....M. F. 1; S. $\frac{1}{1}$.

Actias luna Linnaeus.....M. F. ; S. $\frac{1}{1}$.

Bucculatrix sp.....M. F. 1; R. $\frac{1}{1}$.

Suborder RHOPALOCERA

Anosia plexippus Linnaeus.....M. F. 1; S. $\frac{1}{1}$.

Euptoieta claudia Cramer.....M. F. 3; S. $\frac{3}{3}$.

Phyciodes tharos Drury.....M. F. 3; S. $\frac{4}{4}$.

Junonia genoveva Cramer.....M. F. 5; S. $\frac{7}{7}$.

Neonympha eurytus Fabricius.....M. F. 1; S. $\frac{1}{1}$.

Libythea bachmanni Kirtland.....M. F. 1; S. $\frac{1}{1}$.

Lycaena annetta Mead.....M. F. 1; S. $\frac{1}{1}$.

Lycaena comyntas Godart.....M. F. 2; S. $\frac{2}{2}$.

Pieris occidentalis Reakirt.....M. F. 5; S. $\frac{6}{6}$.

Pieris protodice Boisduval and Leconte.....M. F. 3; S. $\frac{5}{5}$.

Meganostoma caesonia Stoll.....M. F. 1; S. $\frac{2}{2}$.

Colias eurytheme Boisduval.....M. F. 1; S. $\frac{1}{1}$.

Colias ariadne Edwards.....M. F. 1; S. $\frac{1}{1}$.

Colias keewaydin Edwards.....M. F. 2; S. $\frac{2}{2}$.

Colias pelidne Boisduval.....M. F. 2; S. $\frac{2}{2}$.

Terias nicippe Cramer.....M. F. 6; S. $\frac{8}{8}$.

Terias lisa Boisduval and Leconte.....M. F. 2; S. $\frac{2}{2}$.

Papilio daunus Boisduval.....M. F. 1; S. $\frac{1}{1}$.

Hesperia montivaga Reakirt.....M. F. 1; S. $\frac{1}{1}$.

Hesperia xanthus Edwards.....M. F. 1; S. $\frac{3}{2}$.

Thanaos petronius Lintner.....M. F. 1; S. $\frac{1}{1}$.

Order DIPTERA

Diptera larvae.....M. F. 12; R. $\frac{3}{3}$; O. 1. $\frac{2}{2}$; O. 2. $\frac{9}{8}$; O. 3. $\frac{26}{11}$; S. 2. $\frac{10}{8}$; S. 3. $\frac{2}{2}$; C. 1. $\frac{4}{3}$; C. 2. $\frac{62}{5}$; C. 3. $\frac{12}{9}$.

Tipulidae sp. (immature).....M. F. 1; S. $\frac{1}{1}$.

Helobia sp.....M. F. 1; S. $\frac{1}{1}$.

Helobia hybrida Mg.....M. F. 1; O. 1. $\frac{1}{1}$; S. 1. $\frac{1}{1}$.

Limnophila sp.....M. F. 1; S. $\frac{1}{1}$.

Limnophila montana O. S.....M. F. 1; S. $\frac{14}{2}$.

Dactylolabis cubitalis O. S.....M. F. 1; S. $\frac{1}{1}$.

Tipula umbrosa Loew.....M. F. 2; S. $\frac{5}{4}$.

Tipula cunctans Say.....M. F. 3; S. $\frac{26}{6}$.

Atrichopogon levis Coq.....M. F. 6; S. $\frac{60}{10}$.

Atrichopogon fusinervis Mall.....M. F. 1; S. $\frac{1}{1}$.

Forcipomyia specularis Coq.....M. F. 1; S. $\frac{1}{1}$.

Chironomus flavus Joh.....M. F. 1; S. $\frac{1}{1}$.

Orthocladius sp.....M. F. 5; S. $\frac{45}{7}$; O. 1. $\frac{3}{2}$; S. 1. $\frac{1}{1}$.

Sciara sp.....M. F. 1; S. $\frac{1}{1}$.

Sciara grandis Meigen.....M. F. 1; S. $\frac{1}{1}$.

Dilophus breviceps Loew.....M. F. 2; S. $\frac{18}{3}$.

Actina viridis Say.....M. F. 1; S. $\frac{1}{1}$.

Odontomyia sp.....M. F. 1; S. $\frac{1}{1}$.

Nemotelus sp. ..... M. F. 3; S. $\frac{4}{4}$.

Oxycera maculata Olivier ..... M. F. 1; S. $\frac{1}{1}$.

Exoprosopa fasciata Macq. ..... M. F. 1; S. $\frac{2}{2}$.

Anthrax morio Linnaeus ..... M. F. 3; S. $\frac{4}{3}$.

Anthrax sinuosa Wied. ..... M. F. 1; S. $\frac{1}{1}$.

Sparnopolius vulgaris Loew ..... M. F. 1; S. $\frac{1}{1}$.

Rhaphium affilatus Wheeler ..... M. F. 1; S. $\frac{1}{1}$.

Dolichopus sp. ..... M. F. 1; S. $\frac{1}{1}$.

Gymnopternus sp. ..... M. F. 7; S. $\frac{144}{13}$.

Empididae sp. ..... M. F. 3; S. $\frac{7}{4}$.

Euhybos sp. ..... M. F. 2; S. $\frac{2}{2}$.

Euhybos triplex Walker ..... M. F. 2; S. $\frac{1}{1}$.

Empis sp. ..... M. F. 3; S. $\frac{7}{4}$.

Rhamphomyia sp. ..... M. F. 3; S. $\frac{4}{3}$.

Rhamphomyia fumosa Loew ..... M. F. 1; S. $\frac{1}{1}$.

Lonchoptera lutea Panzer ..... M. F. 1; S. $\frac{1}{1}$.

Pipunculus sp. ..... M. F. 1; S. $\frac{1}{1}$.

Syrphus americanus Wied. ..... M. F. 3; S. $\frac{3}{3}$.

Allograpta sp. ..... M. F. 1; S. $\frac{1}{1}$.

Mesogramma marginata Say ..... M. F. 6; S. $\frac{57}{13}$.

Conopidae sp. ..... M. F. 1; S. $\frac{1}{1}$.

Cistogaster occidua Walk. ..... M. F. 1; S. $\frac{1}{1}$.

Cryptomeigenia sp. ..... M. F. 1; S. $\frac{1}{1}$.

Epigrymyia sp. ..... M. F. 1; S. $\frac{1}{1}$.

Phorocera claripennis Macq. ..... M. F. 1; S. $\frac{1}{1}$.

Winthemia sp. ..... M. F. 1; S. $\frac{1}{1}$.

Sarcophaga tenuiventris Vdw. ..... M. F. 2; S. $\frac{1}{1}$; O. 1. $\frac{1}{1}$.

Lucilia sp. ..... M. F. 1; S. $\frac{1}{1}$.

Musca domestica Linnaeus ..... M. F. 1; S. $\frac{1}{1}$.

Anthomyiidae sp. ..... M. F. 5; S. $\frac{31}{14}$.

Fannia sp. ..... M. F. 2; S. $\frac{21}{3}$.

Scatophaga sp. ..... M. F. 2; S. $\frac{3}{3}$; S. 1. $\frac{1}{1}$; C. 1. $\frac{1}{1}$.

Leptocera sp. ..... M. F. 1; S. $\frac{6}{2}$.

Sapromyzidae sp. ..... M. F. 2; R. $\frac{1}{1}$; S. $\frac{6}{3}$.

Lonchaea sp. ..... M. F. 1; S. $\frac{1}{1}$.

Delphinia picta Fab. ..... M. F. 1; S. $\frac{2}{1}$.

Sepsis violacea Meigen ..... M. F. 7; S. $\frac{30}{13}$.

Ephydridae sp. ..... M. F. 6; S. $\frac{18}{9}$.

Scatella sp. ..... M. F. 1; S. $\frac{1}{1}$.

Chloropidae sp. ..... M. F. 4; S. $\frac{20}{7}$.

Chlorops sp. ..... M. F. 6; S. $\frac{28}{9}$.

Oscinella sp. ..... M. F. 9; S. $\frac{57}{18}$.

Drosophila sp. ..... M. F. 2; R. $\frac{1}{1}$; S. $\frac{1}{1}$.

Cerodonta denticornis Panzer ..... M. F. 1; S. $\frac{4}{2}$.

Order COLEOPTERA

Coleoptera larvae ..... M. F. 14; R. $\frac{15}{15}$; S. $\frac{4}{4}$; O. 1. $\frac{6}{5}$; O. 2. $\frac{5}{3}$; O. 3. $\frac{15}{13}$; S. 1. $\frac{3}{2}$; S. 2. $\frac{21}{17}$; S. 3. $\frac{8}{7}$; C. 1. $\frac{3}{3}$; C. 2. $\frac{13}{11}$; C. 3. $\frac{10}{7}$.

Cicindela punctualata Oliv. ..... M. F. 1; S. $\frac{1}{1}$.

Carabus sylvosus Say ..... M. F. 1; S. $\frac{1}{1}$.

Scarites subterraneus Fab. ..... M. F. 1; R. $\frac{1}{1}$.

Clivina bipustulata Fab. ..... M. F. 5; R. $\frac{1}{1}$; O. 2. $\frac{2}{2}$; S. 3. $\frac{1}{1}$.

Aspidoglossa subangulata Chand. ..... M. F. 6; R. $\frac{2}{2}$; S. 1. $\frac{1}{1}$; S. 2. $\frac{3}{3}$; C. 2. $\frac{1}{1}$.

Anillus sp. ..... M. F. 1; R. $\frac{1}{1}$.

Evarthrus colossus Lec. ..... M. F. 1; R. $\frac{1}{1}$.

Platynus punctiformis Say ..... M. F. 7; R. $\frac{15}{8}$.

Brachynus sp. ..... M. F. 1; R. $\frac{1}{1}$.

Harpalus vagans Lec. ..... M. F. 2; R. $\frac{2}{2}$.

Harpalus nitidulus Chd. . . . . M. F. 6; R. $\frac{4}{4}$; S. 1. $\frac{2}{2}$; S. 2. $\frac{4}{2}$; C. 1. $\frac{1}{1}$.

Harpalus pennsylvanicus DeGeer. . . . . M. F. 10; R. $\frac{13}{12}$; O. 1. $\frac{3}{2}$; S. 3. $\frac{1}{1}$; C. 2. $\frac{1}{1}$.

Stenolophus conjunctus Say. . . . . M. F. 5; R. $\frac{6}{6}$; S. 1. $\frac{1}{1}$; S. 3. $\frac{1}{1}$.

Triplectrus dulcicollis Laf. . . . . M. F. 2; R. $\frac{2}{2}$.

Tachistodes testaceus Dej. . . . . M. F. 5; $\frac{4}{2}$; S. $\frac{2}{2}$; O. 1. ; $\frac{1}{1}$ O. 2. $\frac{3}{2}$; S. 1. $\frac{2}{2}$; S. 2. $\frac{2}{2}$. C. 1. $\frac{1}{1}$.

Ferestria obsoleta Say. . . . . M. F. 1; R. $\frac{1}{1}$; S. $\frac{1}{1}$.

Omalium sp. . . . . M. F. 1; S. $\frac{1}{1}$.

Osorius latipes Grav. . . . . M. F. 8; R. $\frac{1}{1}$; S. $\frac{1}{1}$; O. 1. $\frac{4}{3}$; S. 2. $\frac{2}{2}$; S. 3. $\frac{2}{2}$; C. 3. $\frac{1}{1}$.

Coccinellidae larvae . . . . . M. F. 2; R. $\frac{1}{1}$; S. $\frac{1}{1}$.

Cycloneda munda Say. . . . . M. F. 1; S. $\frac{1}{1}$.

Coccinella novemnotata Hbst. . . . . M. F. 1; S. $\frac{1}{1}$.

Scymnus americanus Muls. . . . . M. F. 1; S. $\frac{1}{1}$.

Triplax thoracica Say. . . . . M. F. 1; S. $\frac{1}{1}$.

Hister pollutus Lec. . . . . M. F. 3; R. $\frac{1}{1}$; S. $\frac{3}{2}$; O. 1. $\frac{1}{1}$.

Phelister subrotundus Say. . . . . M. F. 3; R. $\frac{1}{1}$; S. $\frac{2}{2}$.

Elateridae larvae. . . . . M. F. 8; R. $\frac{4}{3}$; O. 2. $\frac{3}{1}$; O. 3. $\frac{2}{2}$; S. 2. $\frac{2}{2}$; S. 3. $\frac{2}{2}$.

Melanotus sp. . . . . M. F. 5; R. $\frac{11}{3}$; O. 1. $\frac{1}{1}$; O. 3. $\frac{2}{2}$; S. 2. $\frac{1}{1}$.

Limonius interstitialis Melsh. . . . . M. F. 1; R. $\frac{1}{1}$.

Conoderus auritus Hbst. . . . . M. F. 3; S. $\frac{1}{1}$; O. 1. $\frac{2}{2}$; O. 2. $\frac{1}{1}$; S. 3. $\frac{1}{1}$.

Chauliognathus marginatus Fab. . . . . M. F. 1; R. $\frac{1}{1}$.

Silis bidentatus Say. . . . . M. F. 2; S. $\frac{2}{1}$; S. 2. $\frac{1}{1}$.

Collops vittatus Say. . . . . M. F. 1; S. $\frac{1}{1}$.

Attalus scincetus Say. . . . . M. F. 1; S. $\frac{1}{1}$.

Enoclerus nigrifrons Say. . . . . M. F. 1; C. 1. $\frac{1}{1}$.

Pinotus carolina Linnaeus. . . . . M. F. 1; R. $\frac{1}{1}$.

Canthon laevis Drury . . . . . M. F. 1; S. 1. $\frac{3}{1}$.

Ataenius cognatus Lec. . . . . M. F. 6; R. $\frac{2}{2}$; S. 2. $\frac{1}{1}$; S. 3. $\frac{1}{1}$; C. 2. $\frac{2}{2}$.

Geotrupes blackburni Fabr.....M. F. 1; C. 1. $\frac{1}{1}$; C. 2. $\frac{1}{1}$.

Cloeotus globosus Say.....M. F. 1; S. 1. $\frac{1}{1}$.

Diplotaxis harperi Blanch.....M. F. 3; R. $\frac{2}{2}$; C. 2. $\frac{1}{1}$; C. 3. $\frac{1}{1}$.

Lachnosterna implicita Horn.....M. F. 1; R. $\frac{1}{1}$.

Batyle suturalis Say.....M. F. 1; S. $\frac{1}{1}$.

Diabrotica duodecimpunctata Oliv.....M. F. 1; S. $\frac{1}{1}$.

Phyllobrotica limbata Fab.....M. F. 1; R. $\frac{1}{1}$; S. 1. $\frac{1}{1}$.

Oedionychus petaurista Fab.....M. F. 1; S. $\frac{1}{1}$.

Disonycha arizonae Cas.....M. F. 2; S. $\frac{2}{2}$.

Hypolampsis pilosa Illig.....M. F. 1; S. 2. $\frac{1}{1}$.

Chaetocnema pulicaria Melsh.....M. F. 3; S. $\frac{5}{5}$.

Systena elongata Fab.....M. F. 3; R. $\frac{1}{1}$; S. $\frac{2}{2}$.

Dibolia borealis Chev.....M. F. 4; S. $\frac{15}{7}$.

Eutochia picea Melsh.....M. F. 2; R. $\frac{4}{1}$; C. 2. $\frac{1}{1}$.

Anaedus brunneus Ziegler.....M. F. 1; R. $\frac{1}{1}$.

Mordellistena sp.....M. F. 1; R. $\frac{1}{1}$.

Mordellistena pustulata Melsh.....M. F. 2; S. $\frac{2}{2}$; S. 2. $\frac{1}{1}$.

Mordellistena cervicalis Lec.....M. F. 3; S. $\frac{6}{3}$; S. 1. $\frac{1}{1}$.

Hyperodes obscurellus Dtz.....M. F. 1; O. 2. $\frac{1}{1}$.

Idiostathus subcalvus Leo.....M. F. 1; S. $\frac{1}{1}$.

Magdalis pandura Say.....M. F. 2; R. $\frac{1}{1}$; S. $\frac{1}{1}$.

Order HYMENOPTERA

Hymenoptera larvae.....M. F. 4; R. $\frac{7}{2}$; O. 1. $\frac{25}{1}$; O. 3. $\frac{6}{2}$.

Emphytus sp.....M. F. 1; S. $\frac{1}{1}$.

Dolerus sp.....M. F. 1; O. 1. $\frac{1}{1}$.

Acordulecera sp.....M. F. 1; S. $\frac{1}{1}$.

Apanteles sp.....M. F. 2; S. $\frac{4}{2}$.

Apanteles femu. nigrum Prov.....M. F. 2; S. $\frac{2}{2}$.

Apanteles ensiger Say.....M. F. 2; S. $\frac{2}{2}$.

Microbracon sp. ..... M. F. 1; S. $\frac{1}{1}$.

Microbracon quinnipiacorum Vier ..... M. F. 1; S. $\frac{1}{1}$.

Microbracon brachyurus Ashm ..... M. F. 1; S. $\frac{1}{1}$.

Opius coriaceus Gah ..... M. F. 4; S. $\frac{19}{8}$.

Coelinidea sp ..... M. F. 1; S. $\frac{1}{1}$.

Heterospilus sp ..... M. F. 1; S. $\frac{1}{1}$.

Meteorus vulgaris Cress ..... M. F. 2; S. $\frac{2}{2}$.

Bassus rubripes Cress ..... M. F. 1; S. $\frac{1}{1}$.

Chelonus sp ..... M. F. 2; S. $\frac{2}{2}$.

Porizon sp ..... M. F. 4; S. $\frac{6}{5}$.

Lissonota sp ..... M. F. 3; S. $\frac{8}{4}$.

Diaeretus sp ..... M. F. 3; S. $\frac{4}{3}$.

Cymodusa distincta Cress ..... M. F. 1; S. $\frac{1}{1}$.

Cymodusa eurycreontis Ashm ..... M. F. 5; S. $\frac{18}{9}$; S. 3. $\frac{1}{1}$

Amblyteles rubicundus Cress ..... M. F. 1; S. $\frac{1}{1}$.

Spilochalcis torvina Cress ..... M. F. 1; S. $\frac{2}{2}$.

Haltichella sp ..... M. F. 1; S. $\frac{1}{1}$.

Mutilla occidentalis L. ..... M. F. 2; S. $\frac{2}{2}$.

Polistes fuscatus rubiginosus Lep ..... M. F. 2; S. $\frac{4}{3}$.

Psen tibialis Cress ..... M. F. 1; S. $\frac{1}{1}$.

Trypoxylon sp ..... M. F. 1; S. $\frac{1}{1}$.

Halictus coreopsis Robertson ..... M. F. 2; S. $\frac{11}{3}$.

Halictus ligatus Say ..... M. F. 3; S. $\frac{5}{3}$.

Halictus sparsus Robertson ..... M. F. 7; S. $\frac{10}{7}$; O. 1. $\frac{1}{1}$; O. 2. $\frac{1}{1}$; C. 1. $\frac{1}{1}$.

Halictus sp ..... M. F. 4; S. $\frac{33}{5}$.

Augochlora cuprea Smith ..... M. F. 1; S. $\frac{1}{1}$.

Augochlora striata Prov ..... M. F. 2; S. $\frac{2}{2}$.

Perdita halictoides Smith ..... M. F. 6; S. $\frac{9}{7}$; O. 1. $\frac{5}{1}$; O. 3. $\frac{1}{1}$; S. 1. $\frac{1}{1}$.

Pseudopanurgus illinoensis Cress ..... M. F. 5; S. $\frac{22}{8}$; O. 3. $\frac{1}{1}$.

Nomada sp. ..... M. F. 2; S. $\frac{4}{3}$.

Hylaeus modestus Say ..... M. F. 1; S. $\frac{1}{1}$.

Apis mellifera Linnaeus ..... M. F. 2; S. $\frac{2}{2}$.

Phileremulus sp. ..... M. F. 1; S. $\frac{1}{1}$.

Andrena arabis Robertson ..... M. F. 1; S. $\frac{2}{2}$.

Andrena cressoni Robertson ..... M. F. 1; S. $\frac{1}{1}$.

Andrena sp. ..... M. F. 1; S. $\frac{1}{1}$.

Monomorium minimum Emery ..... M. F. 7; R. $\frac{169}{6}$; S. $\frac{24}{5}$; O. 1. $\frac{10}{5}$; O. 2. $\frac{27}{2}$; O. 3. $\frac{50}{1}$.

Solenopsis molesta Say ..... M. F. 5; R. $\frac{28}{3}$; O. 1. $\frac{205}{3}$; O. 2. $\frac{224}{3}$; O. 3. $\frac{79}{2}$; S. 2. $\frac{2}{1}$; S. 3. $\frac{1}{1}$; C. 1. $\frac{6}{1}$.

Pheidole pilifera Rog ..... M. F. 2; R. $\frac{2}{2}$.

Pheidole dentata Mayer ..... M. F. 2; R. $\frac{3}{2}$.

Pheidole vinelandica Mayer ..... M. F. 4; R. $\frac{1}{1}$; O. 1. $\frac{4}{3}$; O. 2. $\frac{7}{2}$.

Pheidole sp. ..... M. F. 7; R. $\frac{1}{1}$; S. $\frac{1}{1}$; O. 1. $\frac{34}{6}$; O. 2. $\frac{7}{4}$; O. 3. $\frac{40}{7}$; S. 1. $\frac{10}{4}$; C. 3. $\frac{1}{1}$.

Cremastogaster lineolata Say ..... M. F. 8; R. $\frac{2563}{12}$; S. $\frac{31}{11}$; O. 1. $\frac{44}{6}$; O. 2. $\frac{8}{3}$; O. 3. $\frac{14}{4}$; S. 1. $\frac{2}{2}$; S. 3. $\frac{1}{1}$; C. 1. $\frac{6}{2}$; C. 3. $\frac{1}{1}$.

Cremastogaster victia missouriensis Em ..... M. F. 9; R. $\frac{19}{4}$; S. $\frac{2}{1}$; O. 1. $\frac{3}{1}$; O. 2. $\frac{12}{3}$; O. 3. $\frac{16}{6}$; S. 1. $\frac{5}{3}$; S. 2. $\frac{1}{1}$; S. 3. $\frac{2}{1}$; C. 2. $\frac{1}{1}$.

Cremastogaster victima Smith ..... M. F. 1; S. 3. $\frac{1}{1}$.

Asphaenogaster fulva rudis Em ..... M. F. 1; R. $\frac{1}{1}$.

Aphaenogaster tretae hardeni Wheeler ..... M. F. 5; R. $\frac{4}{4}$; S. 1. $\frac{2}{2}$; C. 1. $\frac{2}{1}$; C. 3. $\frac{3}{1}$.

Asphaenogaster treatae For ..... M. F. 2; R. $\frac{1}{1}$; C. 3. $\frac{1}{1}$.

Leptothorax (Dichothorax) manni Wheeler ..... M. F. 1; O. 1. $\frac{2}{1}$.

Leptothorax (Dichothorax) pergandei Em ..... M. F. 1; S. 3. $\frac{3}{1}$.

Prenolepis imparis testacea Emery ..... M. F. 1; R. $\frac{1}{1}$.

Lasius americanus Emery ..... M. F. 1; R. $\frac{3}{1}$.

Camponotus castaneus americanus Mayer ..... M. F. 3; R. $\frac{3}{3}$.

Ponera coarctata pennsylvanica Buckley ..... M. F. 4; R. $\frac{6}{3}$; S. 3. $\frac{1}{1}$.

Ponera trigona opacior For.....M. F. 1; R. $\frac{1}{1}$.

Iridomyrmex analis Andre.....M. F. 2; R. $\frac{502}{2}$.

Iridomyrmex pruinosus Roger .....M. F. 7; R. $\frac{33}{7}$; S. $\frac{2}{2}$; O. 1. $\frac{3}{2}$; S. 1. $\frac{1}{1}$; S. 3. $\frac{1}{1}$.

Eciton schmitti Emery.....M. F. 2; R. $\frac{50}{1}$; S. 1. $\frac{1}{1}$.

SUMMARY AND CONCLUSIONS

(1) The macroscopic invertebrates of the cedar glades of Middle Tennessee, near Nashville, were collected and classified.

(2) The purpose of the writer's studies was to discover the kind of invertebrates in the cedar glades and to determine the conditions under which they were found.

(3) Weekly field trips were taken during thirteen consecutive months, from October 5, 1929 through November 15, 1930. Animals were collected by digging quadrats, by making sweeps, and turning over rocks. Data on temperature, relative humidity, and evaporation were taken in three typical habitats: Open Habitat, Shrub Habitat, and Cedar Habitat, in which the animals were collected.

(4) The Shrub Habitat had the highest average maximum temperature, 80.31° F., and the Open Habitat had the highest average noon temperature, 68.03° F. at the surface and 66.96° F. at the three foot level. Both the average minimum, 36.86° F. and the average noon temperatures, 65.13° and 65.16° F. were the lowest in the Cedar Habitat. The highest average relative humidities were in the Open Habitat being 57.40 and 55.92% at the surface and at the three foot level. The lowest average relative humidity, 55.09%, at the surface was in the Shrub Habitat. The lowest at the three foot level was in the Cedar Habitat which was 53.67%. The average amounts of water evaporated per week from the black atmometers in the Open Habitat, Shrub Habitat, and Cedar Habitat were 6.225, 5.364 and 5.077 ounces respectively. The white atmometers in the Open Habitat, Shrub Habitat and Cedar Habitat lost 5.655, 4.542 and 5.174 ounces respectively.

(5) Animals of three phyla: Annelida, Mollusca and Arthropoda were collected. The Earthworms were represented by one order, two families, two genera, and five species. The Snails belonged to two orders, four families, five genera, and seven species. The majority of the species collected were Arthropods. The individuals collected belonged to sixteen orders, one hundred and fourteen families, two hundred and eighty-six genera and two hundred and eighty species. All animals found included nineteen orders, one hundred and twenty families, two hundred and ninety-three genera and two hundred and ninety-two species.

(6) No significant difference was found between the animals of the Open Habitat, Shrub Habitat and Cedar Habitat. The same species occurred in all three habitats. One exception was the absence of the nymphs of Tibicon sp. from the Open Habitat. The fauna found under the rocks presented a characteristic aspect.

(7) No detailed animal studies have been made of the maple-beech and oak-hickory areas surrounding the cedar glades, therefore it is not possible to compare and contrast the animals of those areas with those of the cedar glades.

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